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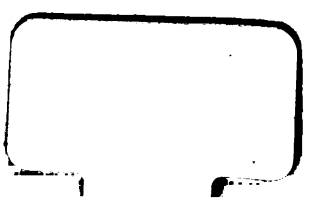
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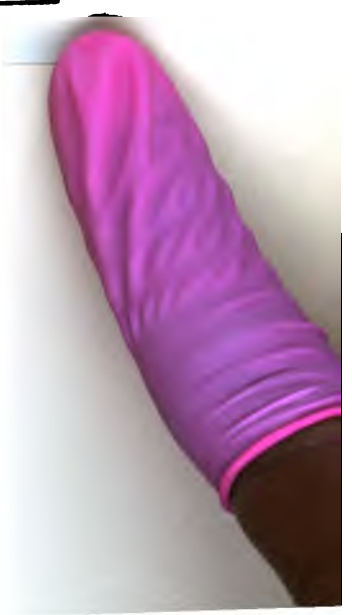
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A TREATISE

ON

CEMENT SPECIFICATIONS

INCLUDING

THE GENERAL USE, PURCHASE, STORAGE, INSPECTION AND TEST REQUIREMENTS OF PORTLAND, NATURAL, PUZZOLAN (SLAG) AND SILICA (SAND) CEMENT

AND

METHODS OF TESTING AND ANALYSIS OF PORTLAND CEMENT

BY

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and Numerous Technical Contributions



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PREFACE

In the preparation of this treatise on specifications for cement (one of the most important materials used in construction work of any magnitude) the constant aim has been to present a set of specifications that would not only be consistent throughout, but which, at the same time, conforms to modern practice. The author is well aware of the fact, however, that no specifications for cement will ever be devised which will meet all mental conditions of engineers and all constructional and manufacturing conditions of actual work, and the following specifications do not perform the impossible, as there are a few matters of detail embraced herein where there is difference of opinion among able engineers, many of whom are at least as competent as the author to determine what is best. It is not expected that all the provisions found herein will be applicable to every class of construction work. A careful study must be made, for reasons which will suggest themselves, of the surrounding conditions and limitations, and these specifications modified in accordance.

In the preparation of these specifications the endeavor has been to observe a logical order and a due proportion between different parts. Great care has been taken in classifying and arranging the specifications and it will be helpful to the reader to notice that they are divided successively into parts, sections and paragraphs. Every precaution has been taken to present the specifications in a form for convenient practical use and ready reference. The table of contents shows the general scope of the specifications and a very full index makes everything in the specifications easy of access.

The engineering periodicals and transactions contain a large number of articles wherein specification requirements for cement

play a very important part in construction work, and hence numerous but carefully selected references to them are made a prominent feature of this work. Besides directing the student and young engineer in his preparation of similar specifications, they encourage him to form the habit of consulting these great cyclopedias of engineering practice. No attempt is made to refer to all the engineering periodicals published in this country nor to include every article on the subject to be found in the periodicals selected. The aim has been merely to give a sufficient number of selected references, to enable the student or young engineer to study the methods employed by others in drawing up cement specifications.

While this work is in some respects imperfect and there is no doubt room for the addition of much information, there has not heretofore been anything like as complete a presentation of the subject; and in consideration of this fact the reader is requested not to be too critical.

JEROME COCHRAN, C.E.

DETROIT, MICHIGAN,
May, 1912.

TABLE OF CONTENTS

PAGE

INTRODUCTION ix
Preparation of Specifications for Cement ix
Selection of Cement xi

PART I

GENERAL CONDITIONS GOVERNING USE OF CEMENT

SEC.

1. General Requirements 1
2. Brand and Composition of Cement 5
3. Silica Cement or Sand Cement 7

PART II

FURNISHING CEMENT TO THE CONTRACTOR

1. General Requirements 9
2. Unnecessary Use and Waste of Cement 11

PART III

PURCHASE OF CEMENT FROM MANUFACTURERS

1. Purchase Tests and Requirements 12
2. Acceptance Tests and Requirements 14
3. Form of Proposal for Furnishing Cement 16

PART IV

DEIVERY AND STORAGE OF CEMENT

1. Delivery of Cement 18
2. Storage of Cement 21

PART V

INSPECTION AND TESTS OF CEMENT

SEC.		PAGE
1.	General Requirements	25
2.	Sampling of Cement for Testing	27
3.	Field Inspection and Tests	28
4.	Laboratory Inspection and Tests	31
5.	Mill Inspection and Tests	34
6.	Acceptance Requirements	37

PART VI

TEST REQUIREMENTS FOR CEMENT

1.	General Requirements	41
2.	Portland Cement	42
3.	Natural Cement	46
4.	Puzzolan or Slag Cement	47
5.	Silica Cement or Sand Cement	48
6.	Additional Requirements	49
7.	Special Requirements (Quick Setting Portland Cement)	49
8.	Cement Used in Sea Water	50

PART VII

METHODS OF TESTING CEMENT

1.	General Requirements	51
2.	Chemical Analysis	52
3.	Fineness of Grinding	52
4.	Specific Gravity	54
5.	Normal Consistency	55
6.	Time of Setting	56
7.	Briquette Making	58
	(*a*) General Requirements	58
	(*b*) Neat Briquettes	60
	(*c*) Sand Briquettes	61
8.	Storage of Test Pieces	63
9.	Tensile Strength	64
10.	Constancy of Volume or Soundness	65
11.	Homogeneity (Microscopical Tests)	67
12.	Miscellaneous Tests	68

PART VIII

SIGNIFICANCE OF TESTS OF CEMENT

SEC. PAGE
1. Sampling Cement for Tests 71
2. Chemical Analysis 71
3. Fineness of Grinding 72
4. Specific Gravity 72
5. Normal Consistency 73
6. Time of Setting 73
7. Tensile Strength 74
8. Constancy of Volume or Soundness 75

PART IX

METHODS OF CHEMICAL ANALYSIS OF PORTLAND CEMENT

1. Solution 77
2. Silica 78
3. Alumina and Iron 78
4. Iron 79
5. Lime 79
6. Magnesia 80
7. Alkalies 80
8. Anhydrous Sulphuric Acid 80
9. Total Sulphur 81
10. Loss on Ignition 81

PART X

BIBLIOGRAPHY OF SPECIFICATIONS FOR CEMENT

1. Storage and Inspection 82
2. Cement Testing in General 82
3. Portland Cement 85
4. Natural Cement 89
5. Puzzolan Cement 91

PART XI

BIBLIOGRAPHY OF FOREIGN CEMENT SPECIFICATIONS 92

INTRODUCTION

It is not customary with American engineers to go into much detail in their specifications for cement. These are generally confined to a distinction between Portland and natural cements, and to a statement of the strength required for each, in briquettes of neat cement and mortar of certain age, the degree of fineness in grinding and constancy of volume or soundness. European engineers, especially on the continent, are more particular. Their classification generally includes six or seven grades; they prescribe certain limits in chemical composition, in specific gravity and the time required for setting and often describe with great detail the manner in which tests are to be made. The specifications of the Ponts et Chaussées for the harbor works of Boulogne and Calais are models in this respect.

PREPARATION OF SPECIFICATIONS FOR CEMENT

The engineer who wishes to compile a specification for cement from the requirements which have been laid down by his predecessors engaged on similar work is confronted by a difficult problem. The great variations in specifications for cement for the same uses seem to be due largely to the failure to recognize the general principles upon which the acceptance or rejection of cement should be based, though, when stated, they seem to be axiomatic.

The specifications should be clear in the matter of indicating what is absolutely required without any alternative, and what is named as indicating in general the character of the product.

The clauses in the specifications should be made so far as possible mutually exclusive. That is to say, no part of the specifications for the general use, purchase, storage, inspection

and test requirements should be specifically described in more than one place.

The good judgment of the engineer must be exercised in his selection of the kind of cement best suited to the work in which it is to be used. His foresight in this particular will decide whether natural hydraulic, puzzolan, or Portland cement shall be used and the grade of the latter. The decision regarding the cement to be used affects the specifications for mortar and concrete.

It is not uncommon to specify that the cement furnished shall be of well-known brands. If possible to avoid it, it is best not to specify a particular brand or proprietary article by name. If this is done at all, more than one such name should be given if possible, and others admitted if shown to be as good as these to the satisfaction of the engineer. To limit the brand of cement to that a single manufacturer subjects the engineer to invidious criticism and suspicion, and it is far better to avoid even the appearance of evil.

The specifications should not require the very highest and best cement the market affords (unless absolutely necessary), but such a grade as would be satisfactory in service, and which can be supplied by the standard manufacturers of that particular product. In this way the engineer gets the benefit of a wide competition, and of a correspondingly low price.

The minimum requirements for cement which serve as a criterion of rejection determines very largely the cost of the work. If, therefore, the engineer in preparing his specifications bases his requirements upon what might be commonly known as good or first-class cement, with a minimum limit fairly below this generally recognized first-class grade, he will usually obtain a cement practically as good as the market affords, without being obliged to pay an extravagant price for it, and without suffering from the delays and troubles caused by the rejection of a large portion of the cement furnished. To base a specification on the very highest tests known of a given cement, and to require this extraordinary quality for all cement furnished is extremely unwise and shows poor judgment.

The above are some of the numerous controlling ideas which the engineer should have clearly in mind in the writing of cement specifications. He must know in the first place exactly what he wants, and then try to so describe it that others cannot mistake

his meaning. If he does not succeed in making clear to the proposed contractors exactly what is wanted, he should feel that he alone is to blame for any misunderstanding.

SELECTION OF CEMENT

The selection of the proper grade of cement to be used in any given structure is, to a great extent, dependent upon the character of the work. For ordinary masonry above ground subjected only to the influence of the weather and to moderate pressures, where the cement acts principally as a binding material, the same grade is not evidently required as for a high masonry dam where impermeability and resistance to crushing are the main requirements, or for a floor or sidewalk covering where hardness is the principal consideration, or for sewer and harbor works where impermeability and ability to resist the chemical action of sewage and sea water are of paramount importance. In other words, the exposure of the work to the weather or its protection from external conditions by position in the interior of piers or foundations or in rock or deep excavations under constant conditions of temperature, moisture, etc., will be prominent in deciding what specifications to adopt for the cement to be used. In all cases, however, that cement should be selected which will give the best and most permanent results consistent with the limits of cost of the work in question. A few general rules may be formulated for guidance in making a selection.

Portland Cement should be used in mortar and concrete for structures subjected to severe or frequently recurring stresses; for structures requiring strength at short periods of time; for reinforced concrete construction; for all work laid under water or which will come into contact with water immediately after placing; for masonry exposed to the action of the elements; and for all other purposes where its cost will be less than that of Natural cement concrete, or mortar of similar quality. White Portland cement is eminently fitted for high class ornamental work.

Natural Cement may be used in concrete for dry unexposed foundations with moderate compression; for backing or filling in massive concrete or stone masonry; for sub-pavements of streets and for sewer foundations; and for use in mortar for

ordinary brickwork, and for ordinary stone masonry where the chief requisite is weight or mass. It should *not* be used in work under water, in marine construction, in columns, beams, floors, or other members subjected to severe or suddenly applied stresses.

Mixtures of Portland and Natural Cements are sometimes employed when quick setting with great strength is desired, but unless mixed at the factory and sold as Improved Natural Hydraulic Cements, are not advisable under any conditions.

Puzzolan or Slag Cement is limited to use in sea water, generally to structures constantly exposed to moisture, as foundations of buildings, sewers and drains, and underground works generally, and in the interior of heavy masonry or concrete. It is unfit for use when subjected to mechanical wear, abrasion, or blows, and should *never* be used where it may be exposed to the action of dry air for long periods. Under such conditions it will turn white and disintegrate, owing to the oxidation of its sulphides to the surface. The low strength, variable composition, and certain properties of slag cement renders it undesirable for reinforced concrete structures.

Silica Cement or Sand Cement is recommended by the U. S. Army Engineers for grouting,* and it is sometimes employed as a substitute for Natural cement.

References. The numbered divisions of the following specifications are herein designated as "paragraphs," each being referred to by the number standing at its beginning.

* Professional Papers No. 28.

CEMENT SPECIFICATIONS

PART I

GENERAL CONDITIONS GOVERNING USE OF CEMENT

1. GENERAL REQUIREMENTS

1. In General. All hydraulic cement shall be equal to the best of its kind and shall be of the grades known as Portland, Natural or Puzzolan, as may be ordered in the work, and must be manufactured by firms of established reputation. Cement must be of good and uniform quality, setting firmly and strongly, but not too quickly. In other words, the best quality of hydraulic cement obtainable in the market shall be used.

2. Use of Portland Cement. Only Portland cement shall be used in reinforced concrete structures or for any construction that will be subject to shocks or vibrations or stresses other than direct compression.

3. Contract Work. Cement used on contract work for the City or Company shall be subject to the same requirements and tests as that purchased direct by the City or Company. (See Part III, page 12).

4. Building Ordinances. The cement shall conform to all the requirements of the building ordinances of the City of No brand of cements which has not met these requirements shall be used.

5. Time of Setting. According to the purpose for which it is intended, quick or slow-setting cement may be demanded. Slow-setting cements are those that set in about two hours or

more. When a specially slow-setting cement is required the minimum time of final setting shall be specified.

6. Preference for Slow-setting Cements. Preference will be given to cements which, by their records, show a tendency to develop strength steadily for long periods, unless for special purposes cement is required that will develop great strength in a short time. A slow-setting cement is preferable, as the work being usually constructed in layers has more chance of becoming incorporated. Portland cement is rendered slower setting by long storage.

7. Varying Cost of Cement. When by order or permission of the Engineer, cements having a higher or lower market value are used, he shall make a fair addition or deduction in the estimates on account of such change.

8. Inspection and Tests. The cement will be subject to inspection and rigorous tests by the Engineer, and none shall be used or remain on the work but that which has been approved by him. (See Part V, page 25). In all cases cement shall be approved by the Engineer, and the Inspector in charge of the work shall receive a written approval before permitting concrete to be made from any cement delivered.

9. Laboratory Inspection and Tests. Inspection and tests shall be conducted by a standard testing laboratory selected by the Engineer and at the cost and expense of the Contractor. (See Part V, Sec. 4, page 31).

10. Mill Inspection and Tests. The Contractor, when placing orders with the manufacturer, must secure from same an agreement to the effect that the Owner or City will be permitted to inspect all cement furnished for his work, at the mill, in accordance with the terms of these specifications. (See Part V, Sec. 5, page 34).

11. Records of Cement Received, Given Out and Rejected. The Contractor shall provide a competent store keeper, who shall keep a record of the dates and quantities of the different lots of cement received, of all cement given out, and for what purposes, and of all rejected cement. Said record and all original bills of lading shall be accessible to the Engineer at all times.

12. Rejection of Cement. Cement found at any time to be unsatisfactory—before, during or after its placing in the work—shall be subject to rejection, even to the extent of taking down

masonry or other work in which unsatisfatcory cement may have been used. No cement will be allowed to be used unless delivered in suitable packages properly branded.

12a. Removal of Rejected Cement. Cement which has been rejected shall, within five (5) days after notice of rejection being given the Contractor, be removed by the Contractor at his sole expense from the site of the work.

12b. Freight on Rejected Cement. In case cement is rejected after reaching the site of the work, the owner of the cement shall be assessed full tariff rates for its transportation both to and from the site of the work over the lines of the Railroad Company.

13. Removing Work Due to Defective Cement. In case the Engineer shall order any work to be taken down because of unsatisfactory cement, the Contractor shall take down such work and as ordered, and shall rebuild it to the satisfaction of the Engineer, with acceptable cement, but the Contractor shall not be entitled to any payment for taking down and rebuilding work for such reason, nor for any materials used therein, notwithstanding that samples of the cement originally used in the work may have passed the prescribed tests.

14. Cement to be Pulverized. When used in the work, the cement shall be free from lumps and partially or wholly set cement, and in all respects satisfactory to the Engineer. If the cement becomes lumpy before being used, it shall be thoroughly pulverized before mixing with sand. Lumps which cannot be broken up with a light blow of the shovel shall be picked out, and only cement which is in perfect condition shall be used. Any cement that has caked so as, in the opinion of the Engineer, to be injured shall be rejected, and shall be removed immediately by the Contractor from the neighborhood of the site, in order to avoid all possibility of its being used on the work.

15. Removing Rubbish. All papers and other rubbish must be carefully removed from cement.

16. Relation of Cement and Aggregate. The proportion of cement to sand and broken stone or gravel shall be chosen after a very careful study of the local conditions and the available materials.

For reinforced concrete construction a density proportion based on 1: 6 should generally be used, i.e., 1 part of cement to a total of 6 parts of fine and coarse aggregates measured separately.

17. Unit of Measure for Cement. The unit of measure for cement shall be the bag as received from the manufacturer having a gross weight of not less than 95 lbs. Such a packed shall be considered as being equal to one (1) cubic foot of cement. Cement lighter than the above must be counted of proportionately less volume.

18. Measuring Cement. Cement shall be measured in the original packages and the packages counted, instead of weighing on scales, since bags or barrels of cement have standard weights. In measuring cement for mortar or concrete, the standard volume of a barrel or bag of cement shall be determined by comparing its net weight with the weight of one cubic foot of thoroughly compacted neat cement. If bags received from the manufacturer contain less than the specified number of pounds of cement the Contractor shall bring up the weight with additional cement. If the bags weigh uniformly more than is here called for the Contractor shall be allowed to remove the excess cement provided each bag thus altered is altered by weight.

19. Weighing Cement. The Inspector shall weigh one bag in forty as the cement is received, in order to check weights. Every facility must be given to the Inspector to properly supervise the process of weighing.

20. Additional Cement. In any of the mixtures stated in the regular specifications for concrete the Engineer may increase the proportions of cement for special reasons in particular places. If the Engineer insists on more cement, the Contract shall be paid cost and 10% extra.

21. Less Cement. If cement is used in less than the specified proportion, the Contractor shall credit the City or Owner for such difference at the price he is paying for cement.

22. Accepted Cement. The Contractor will be required to keep on hand a supply of accepted cement, sufficient to keep the work going until more is accepted. As the accepted cement is removed from the storehouse for use in the work, the tags or labels of acceptance must be removed by the Engineer.

23. Storage of Cement. A suitable place must be provided for the storage of all cements (see Part IV, Sec. 2, page 21).

24. Destroying Sacks. The following unusual clause was taken from specifications used by the City of Cleveland, O.:

"As the cement is used each sack shall be destroyed, and

the cost of the sacks destroyed must be included in the Contractor's bid for the work."

25. Use of Fresh Cement. Contract clauses which specify the use of fresh cement, only, should be discarded, provided the cement is properly housed and kept free from draughts, as Portland cement does not deteriorate by long warehousing.

2. BRAND AND COMPOSITION OF CEMENT

26. Grade of Cement. Only high-grade American or foreign cements of established reputation, which have been made by the same mill and process and used successfully under similar conditions to those of the proposed work, will be considered, and the decision of the Engineer shall be final.

27. Different Brands of Cement. The cement must be of a brand equal in quality to Atlas, Vulcanite, Lehigh, Medusa, Marquette, Universal, or a cement by other manufacturers whose product complies with the required tests and meets the approval of the Engineer. Before beginning to furnish cement the Contractor shall inform the Engineer what brand or brands he proposes to use.

28. List of Brands of Cement to be Furnished Contractor. In order to avoid any delay or useless expense, the Contractor shall obtain from the Engineer a list of brands of cement which will be received if they pass satisfactorily the tests as prescribed elsewhere (see Part VI, page 41), before placing his orders for cement.

29. Requirements for Placing Cement on Acceptable List. No cement will be placed on the list of acceptable brands until complete and satisfactory tests covering a period of at least one year have been made upon the same in an approved laboratory, nor will any brand of cement then be placed on this list or accepted, unless satisfactory evidence can be furnished to show that they have been used successfully, without signs of deterioration, for a period of at least two years in the construction of important work, subject to conditions as severe as those of the proposed work. In other words, it shall be a cement which usage has proven to possess the proper qualifications and uniformity for the work intended.

30. Unknown Brand of Cement. Should the Contractor desire to use a brand of cement not known to the Engineer to have a reputation for uniformity and strength, he shall submit such samples of it as the Engineer may desire; and such length of time as the Engineer may deem necessary will be taken to inquire into the merits of the cement proposed for use. If the result of said examination is satisfactory to the Engineer, the cement will be taken upon the requirements specified herein (see Part VI, page 41), but should said examination prove unsatisfactory, the cement will not be used upon the work, no matter whether it shows the tensile strengths herein required or not.

31. No Change in Brand of Cement Desired. It is desirable that no change in the brand or quality of cement be made throughout the work, and considerable preference will be given to that cement whose makers can guarantee to supply regularly and on time the entire quantity required. After a brand of cement has been accepted by the Engineer and the Contractor has purchased the same, no other brand will be permitted upon the work except by special permission of the Engineer. This clause is to prevent the frequent change of brands, which is always harmful to the work and causes delay in testing. In other words, only one brand of cement should be used on the work, except for good and sufficient reasons.

32. Use of Cement Limited to Three Brands. Unless otherwise permitted, not more than three brands shall be used in the whole work and only one brand shall be used at the same time in any section of the work, this provision being intended to prevent mixing of brands, but it shall not operate to prevent two brands being used in succession on the same day.

33. Color. If more than one brand is used the colors must be such as not to show marked variations in appearance of the completed work.

34. Brand to be Approved. Before any cement will be allowed to be used, the brand and name of the maker must be submitted to and receive the approvad of the Engineer. No brand of cement shall be used in any concrete work which has not been accepted or approved in writing by the Engineer, such acceptance or approval to be based upon regular tests, where possible.

35. Short-time Tests. Where a standard brand of cement is used which has been used in similar work and found satisfactory, it will be approved on short-time tests. If the results of such short-time tests are not satisfactory, or where the cement is a new brand, the quality of which has not been established, the Engineer reserves the right to withhold the use of such cement until any or all of the prescribed tests may be made.

36. Prohibiting Use of Questionable Cement. Short-time tests on cement are not always conclusive on a questionable cement, and long-time tests being impracticable when work is in progress, the Engineer reserves the right to prohibit the use of any cement which has been known to give questionable results in service in other work. Brands of cement without established good reputation, or not heretofore used in the City of..... may be rejected; or they will be accepted only after they satisfactorily pass the twenty-eight (28) day test.

37. Failure of Brand. The failure of a shipment of cement on any work to meet the prescribed requirements may prohibit further use of the same brand on that work or should any brand of cement fail to maintain a uniform standard of strength and quality, said failure will also justify the rejection of any subsequent shipment of the same brand of cement. The Engineer reserves the right to suspend or cancel the use of any brand that in his opinion may develop objectionable qualities after acceptance.

38. Composition. If required, the Contractor shall furnish a certified statement of the chemical composition of the cement and of the raw material from which it is manufactured.

3. SILICA CEMENT OR SAND CEMENT

39. Manufacture. Silica cement or sand cement is a patented article manufactured by grinding together silica or clean sand with Portland cement, by which process the original cementing material is made extremely fine and its capacity to cover surfaces of concrete aggregates is much increased. Sand cement made from equal weights of cement and sand approximates in tensile strength to the neat cement and the material is sold as cement.

40. Preparation. Sand cement shall not be purchased in the market, but shall be made on the work from approved materials, if used for other purposes than for grouting, for which it is peculiarly adapted.

41. Specifications. The silica cements are in a class by themselves and need special specifications.

PART II

FURNISHING CEMENT TO THE CONTRACTOR

1. GENERAL REQUIREMENTS

42. In General. Cement, unless otherwise specified in contracts for masonry, brickwork, concrete, etc., will be furnished by the City or Owner on cars as near as practicable to the site of the work; but the Contractor shall in all cases unload, haul and provide for safely storing it at the site of the work.

43. Charging Cement to the Contractor. (Alternate Clause). The cement for the work has been purchased by the City or Owner. The same is the.....brand and will be charged to the Contractor at($....) dollars per barrel, sacks included.

44. Contract Regarding Sacks. The contract regarding the sacks reads as follows: "Cement to be packed in cloth sacks, four sacks to the barrel. Cloth sacks to be paid for on the same terms as cement. The Cement Company will purchase empty sacks bearing '.....' brand from the original purchaser at ten cents each on their receipt at its works in good condition, subject to its count and inspection. Empty sacks must be returned within ninety days to the Cement Co.,....., ..., freight prepaid and must be properly packed and so marked as to insure complete identification. The Cement Company does not purchase worthless sacks or sacks of other brands than"

45. Credit for Empty Sacks. The Contractor will be held responsible for the return of the full number of empty sacks to the railway station, in as good condition as when received, less unavoidable wear, and will be charged for all lost or damaged sacks at the same rate as paid by the City or Owner. In other words, the City or Owner will credit the account of the Con-

tractor for all credits sent by the above Cement Company for sacks returned according to the conditions cited above. The sacks must be shipped back by freight, in exact accord with the requirements of the Cement Company. Cement sacks will be purchased only from the parties to whom they were originally shipped filled with cement. The Cement Company will not purchase sacks bearing their brands from junk dealers, or, in fact, from any parties other than the original purchasers.

Empty sacks to be returned should be safely tied in bundles of ten or fifteen—giving the name of the sender.

46. Care of Empty Sacks. Whenever cement is delivered to the Contractor in sacks other than paper, the Contractor will be required to return said sacks in good condition. Care shall be taken to have all empty sacks collected and kept dry with as little damage as possible so that they may be returned to the parties from whom the cement was purchased and due credit thus obtained. Any sacks destroyed or lost will be charged to the Contractor at the rate of 10 cents per sack.

47. Delivery of Cement. The cement furnished to the Contractor will be delivered in carload lots on board the cars at the railroad station located most convenient to the work. The Contractor will be held responsible for any damage done to the cement from the time of its delivery or cars until it is accepted in the completed work.

48. Demurrage. The Contractor will be responsible for demurrage to the railroad company, and shall haul the cement from the railroad to the work. The Contractor will be expected to keep himself informed of the arrival of cement at the railroad freight station, and in every case he will be held responsible for demurrage charges and all other expenses incidental to unloading freight cars and hauling from the freight yard.

All cars should be unloaded immediately, unless there is a good reason for not doing so, as in cases of damage or shortage, as a demurrage charge is made by the Railroads, for cars held more than forty-eight hours after they are placed on the siding.

49. Storage of Cement. The Contractor shall furnish suitable warehouses or sheds for storing the cement until used, and will be responsible for any loss of or injury to cement after its delivery at the railroad station. In no case will the Contractor be per-

mitted to retain box cars on the work for the storage of cement. (See Part IV, Sec. 2, page 21.)

50. Verifying Bills. Contractor must check and verify all bills for cement furnished by the City or Owner.

51. Notifying Engineer when Cement is Wanted. The Contractor must give the Engineer at least thirty days' notice as to when he wants the cement delivered, and shall state his requirements in not less than single carload lots.

2. UNNECESSARY USE AND WASTE OF CEMENT

52. In General. The amount of cement furnished the Contractor which is unnecessarily used or wasted and damaged shall be computed as follows:

53. Deduction for Excess. If any concrete structures are built larger than ordered, so that in the aggregate the volume of concrete in any part of the work exceeds that contained within the lines given, by more than five (5) per cent, the Engineer shall make an estimate of the amount of cement contained in the concrete in excess of the volume contained within the lines given for the work or that part thereof built larger than ordered, and shall charge it to the Contractor; but otherwise no deduction shall be made for cement used in masonry built larger than ordered.

54. Cement Charged to Contractor. The Contractor shall further be charged with the cement required for making concrete to replace any and all concrete rejected, removed and replaced with new concrete under these specifications. The Contractor shall also be charged with all cement in concrete abandoned before being placed, when work is stopped at noon or at night or on account of rain or otherwise; with cement in concrete spoiled or lost, in mixing and in transmission; with cement spoiled or wasted in transit from the storehouse to the work or on the work, and cement spilled or spoiled in the storehouse for any reason whatever, and for all losses of cement of every description in connection with the work; provided, however, that if the work is handled with due care to prevent such waste and loss, and if all such losses in the aggregate amount to two (2) per cent or less of the gross amount of cement used these specifications, no deduction shall be made.

PART III

PURCHASE OF CEMENT FROM MANUFACTURERS

1. PURCHASE TESTS AND REQUIREMENTS

55. In General. Purchase tests on samples furnished by the bidder shall be made to ascertain whether the bidder may be held on the sample to the delivery of suitable material, should his bid be accepted.

56. Brand of Cement. Bidders will state the brand of cement which they propose to furnish. The cement must be of brands in successful use on large engineering works in America for at least five years and come from mills in successful operation for at least two years.

57. Reputation of Manufacturers. Proposals shall be limited to manufacturers of cement of established repute. Lack of commercial standing on the part of the bidder will constitute good and sufficient ground for the rejection of his bid. Cement will be accepted from reliable manufacturers of well-established reputation only.

58. Known Brand of Cement. Sample packages may not be required with the proposal when the brand is known to the Engineer by previous use. Acceptance tests, however, shall be based upon the known qualities of the brand as shown by previous tests.

59. Unknown Brand of Cement. When the cement is not known to the Engineer by previous use, a barrel of it shall be required as representing the quality of cement to be supplied. A full set of tests shall be made from this sample, and subsequent deliveries shall be required to show quality at least equal to the same.

60. Tenders. Tenders will be received only from manufacturers or their authorized agents.

61. Samples. Prior to the award of contracts, parties wishing to be considered will submit samples duly marked for identification, and each guaranteed to be an average sample of the cement to be furnished in the event of the award. The samples will be used for preliminary tests and also preserved for comparison with the cement delivered for use. In case of rejection, sample upon which test is based to be held for one month at the disposal of the shipper.

62. Sampling Cement Submitted by Bidder. The sample barrel of cement shall not be broken further than to take therefrom the necessary samples for testing. Afterwards it shall be put away in a dry place and kept for further testing, should the results obtained be disputed.

63. Method of Testing Cement. All tests shall be made in accordance with the methods proposed by the Committee on Uniform Tests of Cement of the American Society of Civil Engineers, presented to the society Jan. 21, 1903, and amended Jan. 20, 1904, with all subsequent amendments thereto. (See also Part VII, page 51.)

64. Cost of Testing Cement. Parties making propositions for furnishing cement will include in their prices a sum sufficient to cover the cost of having the cement regularly sampled and tested in a manner satisfactory to the Engineer.

65. Information Required. All desired information as to place, materials and method of manufacture shall be furnished whenever desired by the Engineer.

66. Aeration of Cement. Manufacturers must guarantee that all cement has been seasoned or subjected aeration at least thirty days before leaving the works.

67. Delivery of Cement. Cement shall be delivered in such quantities and at such times as the City or Owner may direct, unloaded in a warehouse which shall be located within the limits of the City of....., and no extra charge shall be made for storage or delivery. A man satisfactory to the City or Owner shall be furnished by the Contractor to assist in unloading. (See Part IV, page 18).

68. Empty Sacks. The sacks to be the property of the City or Owner, and each bidder shall state in connection with his bid, the price per cloth sack he will pay for each empty sack delivered at the warehouse aforesaid.

69. Rights Reserved. The right is reserved to reject a tender for any brand of cement which has not established itself as a high-grade cement and which has not given satisfaction in use under climatic or other conditions of exposure of at least equal severity to those of the work proposed. The right is also reserved to reject any cement submitted by the bidder not equal in quality to the standard mentioned elsewhere. (See Part VI, page 41.)

2. ACCEPTANCE TESTS AND REQUIREMENTS

70. In General. Acceptance tests on samples taken at random from deliveries shall be made to ascertain whether the cement supplied accords with the purchase sample, or is suitable for the purpose of the work, as stated in the specifications for cement supplies. If the purchase sample shows higher tests than those above, the average of tests made on subsequent shipments must come up to those found with the sample.

71. Quality of Cement Furnished. The standard of the cement furnished by the manufacturer shall be maintained in quality, burning, fineness, chemical analysis, physical tests, and in every respect equal to the sample accepted.

72. Testing Cement Furnished According to Contract. An agent of the manufacturer may be present at the making of any tests, or, in case of the failure of any of them, they may be repeated in his presence. If the manufacturer so desires, the Engineer may, if he deems it to the interest of the City or Owner, have any or all of the tests made or repeated at some recognized standard testing laboratory in the manner specified elsewhere (see Part VII, page 51). All expenses of such tests shall be paid by the manufacturer, and all such tests shall be made on samples furnished by the Engineer from cement actually delivered to him.

73. Sampling Cement. Cement from one barrel out of each lot of ten barrels of a shipment shall be tested or if so required by the Engineer, samples for testing may be taken from each and every barrel delivered. (See Part V, Sec. 2, page 27.)

74. Manufacturer Furnishing Result of Tests. The cement companies shall send with every shipment of cement a sworn statement showing the result of seven-day and twenty-eight-day

tests, using one part of cement to three parts of sand, by weight, in making briquettes. Cement from one barrel out of each lot of ten barrels of a shipment shall be tested by the manufacturer.

75. Physical Tests, where Made. The above tests shall be made by a firm of cement testers, satisfactory to the Engineer, and each barrel of a shipment shall be stamped with the initials of the cement tester, the date when cement was tested, and the number of the barrel. (See Part V, Sec. 4, page 31.)

76. Chemical Analysis of Cement. A chemical analysis of the cement shall be made by a chemist satisfactory to the Engineer and all expenses of said analysis shall be borne by the cement company furnishing the cement, or its agent.

77. Limits of Accuracy. Chemical determinations will be considered accurate to the nearest tenth of a per cent; tensile tests to the nearest ten pounds. Within these limits must meet the requirements of specifications or the cement will be rejected. There will be no retests.

78. Mill Inspection and Tests. The Engineer is to be given by the manufacturer all facilities required by him to inspect the mill where the cement to be furnished under this contract is being manufactured; or to examine at all times the plant of any part thereof, or any material used in the manufacturing process, or the methods employed in the production and handling of the cements. (See Part V, Sec. 5, page 34.)

79. Tools, Labor, etc. The manufacturer is to furnish to the Engineer the use of such instruments, tools and implements, and materials and labor required in the opinion of the Engineer to satisfactorily carry on the necessary inspection and tests.

80. Compensation for Mill Inspection and Tests. The manufacturer is not to claim any extra compensation for any services thus rendered for the purpose of mill inspection and tests, but it is understood and agreed that the price of his proposal covers all such services and cost of material and labor.

81. Weight. All cement shall be packed in barrels or in sacks, four sacks per barrel for Portland and Puzzolan, and two or three sacks per barrel for Natural cement; 380 lbs. net of Portland cement, 330 lbs. net of Puzzolan and 300 lbs. (west of the Allegheny Mountains this may be 265 lbs.) net of Natural cement shall be considered a barrel, and all cement accepted shall be paid for on this basis.

82. Shortage. The packages shall be of full specified weight. If the average net weight, as determined by test weighings, is found to be below the required weight per barrel, the cement may be rejected, or, at the option of the Engineer, the manufacturer may be required to supply free of cost to the City or Owner an additional amount of cement equal to the shortage.

83. Damaged Cement. Any packages in which the cement has been damaged by moisture before delivery to the City or Owner, will be rejected, and, if numerous, the whole carload or boatload may, at the discretion of the Engineer, be rejected without further test.

84. Rejected Cement. All cement rejected by the City or Owner, through failure to stand the required tests (see Part VI, page 41), or for any other good and sufficient reason, shall be at once removed at the expense of the manufacturer. That is to say, cement rejected on account of failure to meet the specified requirements will be held subject to the order of the shipper and at his expense for freight charges to and from the point where the cement was to have been used. The manufacturer shall promptly replace said defective cement with other cement that will satisfactorily comply with the tests.

3. FORM OF PROPOSAL FOR FURNISHING CEMENT

85. Ordinary Blank Form of Proposal. In adopting the following form of proposal for cement the author has adopted what seems to be a rational subdivision, and one that does not depart materi lly from established forms in general use.

PROPOSAL FOR FURNISHING CEMENT

....., ...
....., 191..

HONORABLE BOARD OF COMMISSIONERS OF THE DEPARTMENT OF PUBLIC WORKS OF THE CITY OF.....:

GENTLEMEN:, the undersigned, propose to furnish, under the above specifications (or the accompanying specifications), on the work, when ordered by the Engineer, Portland cement and Natural cement for the following prices. The net

weights given are the net weights of each brand and package of cement:

For brand of Portland cement in cloth sacks at $.... per barrel of lbs.

Above brand in paper sacks at $.... per barrel of.....

For brand of Portland cement in cloth sacks at $.... per barrel of lbs.

Above brand in paper sacks at $.... per barrel of.....

For brand of Portland cement in cloth sacks at $.... per barrel of lbs.

Above brand in paper sacks at $.... per barrel of.....

For brand of Natural cement in paper sacks at $.... per barrel of lbs.

For brand of Natural cement in paper sacks at $.... per barrel of lbs.

Quantity required, ... to bbls.

Times of delivery, ... to bbls. per week, as may be required by the Engineer; first lot to be delivered

Place of delivery, F.O.B., cars on track at City Yard.

The following Blanks are to be filled by the Bidder:

Place of manufacture

Date of manufacture

A rebate of cents will be allowed for the return of all cloth sacks in good shape.

Enclosed please find certified check on bank for Two Hundred and Fifty ($250.00) Dollars, payable to the City of, which will be forfeited to the City of.....should being the successful bidder, fail to make approved bond for the faithful performance of the contract.

Respectfully submitted,

.....

.....

Any alteration of this sheet will invalidate tender.

Tenders will be received not later than, addressed to Honorable Board of Commissioners of the Department of Public Works, City Hall, ...

.....

City Engineer.

PART IV

DELIVERY AND STORAGE OF CEMENT

1. DELIVERY OF CEMENT

86. In General. All cement must be furnished in the origina package, either in first-class barrels or in stout paper, cloth or canvas bags, which shall be plainly marked with the brand or trademark of the manufacturer of the cement. It must be delivered in good condition, perfectly dry and free from lumps. No cement without the maker's brand will be received. The cement shall be furnished in unbroken packages.

87. Aeration of Cement. No cement shall be shipped until at least thirty (30) days after its manufacture, except that in case of an emergency, and with the approval of the Engineer, a shorter time may be allowed, but if the cement shows indications of unsoundness, a longer time may be required.

88. Certificate from Manufacturer. The manufacturer shall give a written certificate with each shipment of cement, stating (1) the date of manufacture; (2) the tests and analyses which have been obtained at the manufacturer's laboratory for cement taken from the day's grinding, of which the shipment forms a part; (3) that the cement does not contain any adulteration.

88a. Chemical Analysis. For each lot of 500 barrels, or more, the Contractor shall supply a certified chemical analysis from the mill of a mixed sample of the cement taken from any ten barrels. If the cement is supplied in bags, a chemical analysis of an amount equivalent to that specified for barrels shall be furnished.

89. Responsibility for Delivery. In all cases the Contractor shall be responsible for the delivery of the cement in good condition at the place of consignment. The cement must be protected during transportation from rain and moisture.

90. Deterioration of Cement in Transit. To guard against deterioration the packages shall be received unbroken and dry and the cement shall be of good appearance and free from injurious lumpiness.

91. Packages. No cement will be inspected or allowed to be used unless delivered in suitable packages properly branded. These packages may be either barrels or bags, but must be well protected in either case from air and moisture. The packages shall be of full specified weight. Any broken packages may be rejected or used at the option of the Engineer.

92. Meaning of Original Packages. Original packages in these specifications means the bags or barrels coming from the mill with the maker's name thereon. It will be insisted upon that each package be plainly labeled with the name of the brand and of the manufacturer.

93. Mixing of Brands. All barrels or sacks must have the brand and maker's name distinctly marked. No mixing of brands will be allowed.

94. Capacity of Packages. A bag of cement shall contain ninety-four (94) pounds of cement, net. Each barrel of Portland cement shall contain four (4) bags of the above net weight. Each barrel of natural cement shall contain three (3) bags of the above net weight. A cement bag may be assumed to weigh one pound.

95. Packing and Variation in Weight. The gross weight must be marked on the barrels. In case the cement is wanted in barrels of different weight or in sacks, the gross weight must likewise be plainly marked thereon. Leakage, as well as possible variations in individual cases, are allowable to an extent of two (2%) per cent. Provided, however, that not more than five (5%) per cent of any portion of a shipment falls more than two (2%) per cent in weight below the standard or specified weight. If such a variation in weight occurs, it will be cause for rejection of the entire lot.

96. Delivery of Cement in Barrels. Each barrel must be properly lined with paper or other material so as to effectually protect the cement from dampness. Any cement damaged by water to such an extent that the damage can be ascertained from the outside will be rejected *in toto* and the barrels unopened. Barrels containing a large proportion of lumps will also be

rejected. Broken barrels of cement, if otherwise satisfactory, will be counted as half-barrels.

97. Delivery of Cement in Cloth Sacks. The cement shall be put up in stout cloth or canvas sacks. The sacks shall be of good quality and sound. Sacks made of open material, or worn, will with their contents be rejected. That is to say, any sacks broken or containing damaged cement may be rejected or accepted as a fractional sack, at the option of the Engineer.

98. Delivery of Cement in Paper Sacks. The cement must be furnished in strong, perfect paper sacks.

99. Time of Delivery. The Contractor shall furnish the cement upon the work at least ten (10) days before it is to be used, in order that time may be given to make the necessary tests. That is to say, cement must be on hand for testing in time to complete all tests before the cement is required for use in the work, which shall not be more than ten days.

100. Delivery of Cement at Warehouse. All cement required on the work shall be delivered in such quantities and at such times as the Engineer may direct, unloaded in a warehouse or a shed suitable for storing cement, and no extra charge shall be made by the Contractor for storage or delivery.

101. Notice of Delivery. The Contractor shall notify the Engineer when deliveries are to be made a sufficient time in advance so as to allow the Engineer to have a representative present to sample the cement; or he shall rehandle the cement in the storehouse for the purpose of obtaining samples, as directed by the Engineer. The Contractor shall promptly notify the Engineer of receipt of consignments. The Engineer should be notified of each delivery of cement, at least two weeks before it will be needed in the work.

102. Delay in Delivery. Delay in the delivery of cement may prohibit the use of the same brand upon the works, if such delay causes inconvenience in the execution of the work.

103. Unloading Cars. Cement which is delivered on board cars must be unloaded promptly and properly stored, and the cars returned to the Railroad Company's service. In no case will it be permitted to retain box cars on the work for the storage of cement. Cars which may be held shall be charged to the Contractor for each day after the second so held unloaded.

104. Bills of Lading. All original bills of lading shall be accessible to the Engineer at all times. That is to say, the Contractor must furnish to the City or its Engineer the original invoices of all shipments, if so requested.

105. Copy of Mill Tests. The Contractor must furnish to the City or Owner authentic copies of the manufacturer's mill tests of each shipment.

106. Rejection. Cement showing signs of damage from moisture or other causes, such as caking, lumpiness or other defects may be rejected without testing.

2. STORAGE OF CEMENT

107. In General. The Contractor shall be responsible for the proper care of the cement after it has been received and stored, and any cement injured through carelessness or neglect shall be rejected promptly by the Engineer or the Inspector in charge. The cement must be protected from moisture until used. Piling sacks directly on ground will not be permitted. Great care must be exercised to protect the cement against moisture and drafts. No cement in cloth sacks may be used unless properly housed. If the cement is to be stored in a damp place or near the sea, it must be packed in well-made wooden barrels lined with paper. Cement must never be placed on the ground without proper blockings.

108. Deterioration of Cement in Storage. To guard against deterioration the cement shall be stored in dry, well-ventilated buildings and protected from moisture. It may be rejected for such deterioration, after passing the required tests. In all cases where cement has been long stored it shall be carefully tested before use to ascertain whether it has deteriorated in strength.

109. Housing. Cement shall be stored in dry, well-ventilated buildings for work of any magnitude; and for work of less importance it shall be safely stored and protected from moisture in any form.

110. Weather-tight Shed or Storehouse. All cement for use in the work shall be stored (unless otherwise specified) in a

weather-tight shed or building provided by the Contractor for that purpose, near the concrete mixer or mixers. The storehouse shall be raised at least six inches above the ground so as to keep the cement dry, and the sides and roof shall be watertight to protect the cement from rain or the injurious effects of the elements, namely air currents or other source of injury. The house shall be sufficiently large so that the different lots of cement can be kept separate and readily accessible. The cement house shall be provided with suitable scales for weighing the cement.

111. Capacity of Storeroom. The storage room shall be so arranged that each separate lot of not more than two hundred (200) barrels can be stored in a separate bin or in such approved manner as to make it convenient to identify each individual lot in the case of its rejection or in case of the necessity for future tests.

112. Engineer Allowed to Enter Storeroom. The Engineer and his authorized representatives shall be permitted to enter, at any time, all places where cement is kept.

113. Storage of Cement in Carload Lots. The cement shall be stored in such manner as to enable each carload lot to be kept separate and be tagged with car number and date of receipt. One car load shall not be placed immediately upon another.

114. Storage of Cement for Sampling and Marking. The cement shall be piled in tiers in the storehouse in such a manner as to permit easy access for proper inspection and identification. Each lot or consignment received must be piled by itself and its date of receipt plainly indicated. In other words, the cement must be piled in such a manner as to keep different consignments separate and apart and to give access for sampling and marking to any bag or barrel desired. It must also be piled up so that the oldest will come out first. No sample will be taken by the Inspector until cement is piled as herein directed, as it will be his duty to insist that it be stored for ready removal of any lot condemned.

115. Storage of Cement for Use. Different lots of cement must be kept separate, and under no conditions are subsequent lots of cement to be piled upon or in front of old cement already in the warehouse. Previous lots of cement are to be used up

before taking from the newer lots, unless specially directed otherwise by the Engineer.

116. Ample Supply of Cement for Testing. The Contractor shall at all times keep in store a sufficient quantity of cement to allow at least ten (10) days to elapse between the time of testing and the time of using (holidays and Sundays excluded).

117. Untested Cement. Any untested cement received on the work is subject to the same inspection and tests as at the mill (see Part V, Sec. 5, page 34), and must be kept separate from inspected cement.

118. Supply of Accepted Cement. The Contractor shall keep in storage a quantity of accepted cement sufficient to insure the uninterrupted progress of the work.

119. Failure to Provide Necessary Amount of Approved Cement. Should the Contractor's work be delayed by his failure to keep himself supplied with the necessary amount of approved cement, the City or Owner shall have the right to furnish him with tested cement from any stock on hand and charge said Contractor with the cost of same at the rate of $.... per barrel for each and every barrel so furnished, and collect the amount due therefor from any moneys found to be due to said Contractor by the City or Owner.

120. Disturbance of Cards, Marks or Numbers. The Contractor or any of his employees shall not destroy, alter or otherwise disturb any cards, marks or numbers the Engineer shall place upon the storage bins or packages of cement as an aid to their future identification.

121. Storage of Cement in the Open. Storage of cement in the open shall be limited to small quantities to be used immediately in the work. Bags of cement shall not be piled on wet ground, but on planking, sidewalk, pavement, etc., so that no part of the packages shall be nearer than four (4) inches to the ground or pavement, and they shall be stacked in compact piles which can be covered with tarpaulin in case of showers. The Contractor shall see that tarpaulins are provided and are ready for immediate use. The cement must not be allowed to become wet or damp under any circumstances and must be effectually covered so that rain cannot reach it.

122. Preservation of Maker's Brand. The maker's brand on all cement must be preserved upon casks or packages.

123. Weighing Cement. The Contractor shall provide suitable scales for weighing cement. If the cement is turned out of the bags or barrels for the purpose of storing, it shall be weighed again as rebagged or packed when used for measuring cement in mixing concrete, and each bag or barrel must contain no less weight of cement than the required unit.

124. Setting Qualities. Portland cement is rendered slower setting by long storage, and its tensile strength is increased if kept in a dry place free from draughts.

PART V

INSPECTION AND TESTS OF CEMENT

1. GENERAL REQUIREMENTS

125. In General. All cement must be inspected. It may be inspected either at the place of manufacture or on the work, or both, as may be ordered by the Engineer. It may also be stopped in transit, on line of road, for a sufficient length of time to allow the lot to be sampled.

126. Lumpy Cement. Lumpy cement to be rejected or pulverized, as directed by the Engineer. In general, lumpy cement should not be broken up and used again, as it has lost by far the greater part of its adhesive value. If not easily crushed the cement has probably been affected by dampness, but if easily crushed there is simply an indication of a seasoned cement.

127. Engineer May Test and Analyze Cement. The Engineer shall be allowed to test and analyze all cement, and any cement which is not satisfactory to him shall be at once removed from the work.

128. Factory Inspection. The Engineer or his authorized representative shall at all times have liberty to inspect the materials, process of manufacture, daily laboratory records of analyses and tests at the cement works. (See Sec. 5, page 34.)

129. Number of Barrels Covered by One Set of Tests. If cement is inspected at the work not more than 150 barrels shall be covered by one set of tests. If inspected at the place of manufacture not more than 200 barrels shall be covered by one set of tests.

130. Uniformity of Product. When a given brand of cement has been tested for some time and found to be fairly uniform in its action under the different tests, a sudden wide variation from this normal action in any kind of test shall be looked upon with

suspicion and shall lead to more extended and longer time tests. In other words, cement shall be of uniform fineness, strength, specific gravity, etc., and shall require a uniform amount of mixing water.

131. Extended Tests. The Engineer shall have the right to make any other tests, or use any other means in his power, to gain information as to the quality of cement, and reserves the right to reject any cement which he is not fully satisfied is suitable for the work for which it is intended.

132. Reinforced Concrete Buildings. Tests of cement used in reinforced concrete building operations shall be made from time to time under the supervision of the Building Department in accordance with its requirements.

133. Adulteration. The question of adulteration of the cement may be determined either by chemical analyses or by inspection of the process of manufacture at the factory.

134. Samples. Samples of cement shall be furnished in such manner and at such times as may be required by the Engineer for testing purposes. The samples will be thoroughly mixed together while dry and the mixture be taken as the sample for test. Any cement showing by sample higher tests than those given must maintain the average so shown in subsequent deliveries.

135. Sand for Cement Tests. The sand required for the cement test shall be that specified in the construction in which the cement is to be used.

For tests to be made at other points than the place of delivery, the sand will be furnished free to the Contractor.

136. Tested Cement. The Inspector shall receive a written approval from the Engineer before permitting concrete to be made from any cement delivered and it shall be his duty to make certain that only tested cement is used in the work.

137. Extension of Time. No extension of time on contract will be allowed for delay caused by holding cement for tests herein described.

138. Engineer's Decision. The decision of the Engineer to reject any cement shall be final. In reaching a decision he may, according to his own judgment, assign to all or any of the tests such relative importance as he may consider proper under the circumstances. In other words, the engineer makes the tests upon such proportions of the whole amount of cement as he

sees fit and his decision is final. He can refuse to accept cement without test and without giving his reasons.

2. SAMPLING OF CEMENT FOR TESTING

139. In General. Samples for test may be taken from every package in each shipment of cement, and unless they meet the requirements herein specified (see Part VI, page 41), the whole shipment from which the samples were taken will be rejected. Samples for testing shall be furnished at such times and in such manner as may be required. The selection of the sample for testing, the number of packages sampled, and the quantity taken from each package, must be left to the discretion of the Engineer, but each sample shall be a fair average of the contents of the package from which it is taken. The total sample should weigh about 10 lbs. At least one barrel in every ten should be sampled.

140. Facilities for Sampling. The Contractor shall afford the Engineer all reasonable facilities for sampling cement.

141. Carload Lots. The cement for testing may be selected by taking from each of six well-distributed barrels or bags in every carload or fraction thereof, sufficient cement to make five to ten briquettes. These six portions, after being thrown together and thoroughly mixed will be assumed to represent the average of the whole carload, and the acceptance or rejection of the entire carload will depend upon the results of the examination of this sample.

142. Mixing Samples. The samplings shall be thoroughly mixed together when taken so as to constitute as nearly as possible a fair average sample of the whole lot represented. For determining the characteristics of a carload of cement the individual samples may be mixed and the average tested; where time will permit, however, each sample should be tested separately.

143. Not Mixing Samples. (Alternate Clause). Cement drawn from several sample packages should not be mixed or mingled, but the individuality of each sample package should be preserved. All materials taken from the same sample package may be thoroughly mixed or mingled and the tests be made therefrom as showing the true character of the contents of the sample package.

144. Method of Sampling. Samples shall be taken at random from sound packages. Cement in barrels shall be sampled through a hole made in the center of one of the staves, midway between the heads, or in the head, by means of an auger or a sampling iron similar to that used by inspectors of flour or sugar. If in bags, the cement shall be taken from the surface to center.

3. FIELD INSPECTION AND TESTS *

145. In General. Cement will be inspected and tested after delivery at the site of the work. Tests shall be made to ascertain whether the article supplied is genuine cement, of a brand previously tested and accepted, and whether it is reasonably sound and active cement that will set hard in the desired time, and give a good, hard mortar. No cement will be inspected unless delivered in suitable packages properly branded. Tests and analyses will be made of all cements, and any cement which is not satisfactory to the Engineer shall be removed from the work. Such proportion of the number of bags received in a lot shall be sampled for testing as the Engineer shall require.

146. Facility for Testing. Every facility for inspecting and testing the cement shall be furnished by the Contractor. In order to facilitate the testing of the cement the Contractor shall keep a sufficient quantity on hand.

147. Cement Testing House. The Contractor will be required to furnish a small, rough board building or room on the work for cement testing, furnished with shelving, racks, benches and work table to the satisfaction of the Engineer. A steam pipe must be run into the same and sufficient heat furnished to prevent freezing either during the day or at night in cold weather. The expense of such, together with the fitting up and warming of the same, must be included in the whole work.

148. Simple Field Tests. In addition to the usual tests the Inspector will be required, from time to time, to make pats and balls of pure cement, and of cement mixed with sand, in order to satisfy himself that the cement going into the work is

* The preferred practice of engineers is to inspect and test the cement after it has been received in the field.

uniform in character and has not been injured by exposure to weather or in any other way.

149. Setting Qualities. The setting or hardening qualities, as determined roughly by estimating time and by pressure of the thumbnail, shall be observed; the hardness of the set and strength, by cracking the hardened pats or cakes between the fingers, and by dropping the balls from the height of the arm upon a pavement or stone and observing the result of the impact. The Inspector may reject any cement which fails to set properly in sample pats.

150. Change of Volume. Pats shall be placed in water as soon as hardened sufficiently and raising the temperature to the boiling-point for a few hours and observing the character and color of the fracture after sufficient immersion. This will give some idea of the character of the material, whether hydraulic, a Portland or Pozzulan, whether too fresh or possibly " blown," may be speedily and quite well ascertained without measuring instruments.

When subjected to standard tests for constancy of volume, the cement shall show no tendency to swell or crack.

151. Mortar Box Tests. Tests may be made from the mortar box if desired by the Engineer and should they prove unsatisfactory the Contractor must change his brand or improve his method of mixing.

152. Elaborate Tests. The more elaborate tests, described on page 31, shall be made in well-equipped laboratories by skilled cement testers. (See Sec. 4, Laboratory Tests, page 31.)

153. Marking Packages. Every bag or barrel of cement shall be marked by the Inspector, or other precautions may be taken so as to identify the lot from which it is taken and to insure that no cement is delivered for use in the work which has not passed the required tests. Any packages of cement which cannot be so identified may be rejected.

154. Inspection Marks of Acceptance. Inspection marks of acceptance, placed upon barrels or packages, shall be carefully preserved by the Contractor and under no circumstances shall the Contractor allow such marks to be imitated.

155. Inspection Marks of Projection. On all barrels of rejected cement inspection marks will be placed, and the Contractor shall in no case allow these barrels to be used.

156. Reinspection, Test and Rejection of Cement. The fact that cement is satisfactory when tested is not an indication that it will continue to be, hence cement which is not used for some time after test, may be tested again, and if found to be damaged or of improper quality, will be rejected. In other words, cement may be reinspected at any time deemed advisable and if found to be defective, shall be condemned. Tests of cement may be repeated as many times as are deemed necessary by the Engineer.

157. Repeating Tests at a Standard Testing Laboratory. In case the cement fails to meet satisfactorily the tests required, if the manufacturer or Contractor so desires, the Engineer may, if he deems it to the interest of the City or Owner, have all or any of the tests made or repeated at some recognized standard testing laboratory. All expense of such tests to be paid by the Manufacturer or Contractor interested. All such tests shall be made on samples furnished by the City's or Owner's Inspector and same shall, as near as possible, be a duplicate of the sample on which the original tests were made. The methods of making all tests must be approved by the City's or Owner's Inspector.

158. Samples. Samples for testing shall be taken from such number of packages in any carload lot or shipment as the Engineer or the Inspector may select. (Sec. 2, page 27.)

159. Cement Inspection for City Work. As soon as a carload of cement arrives for the Contractor doing work for the City, the Engineer shall be notified and a sampler will be started at once to take samples from about one bag in 35 as they are being removed from the car to the storehouse.

The bin in which the cement is placed shall then be tagged with white cards, about 4×5 ins. in size, bearing a serial number in large size type and the word "HOLD," together with spaces for car number, number of bags in the car, and the bin number and date sampled. When the cement has passed the laboratory tests (see Sec. 4, page 31), the white card shall be removed and a pink one substituted, bearing the word "RELEASED." The Inspector can thus see at a glance whether or not the Contractor is using cement from an approved lot. When the bin is empty the pink card shall be returned to the laboratory.

Each Saturday all Inspectors shall mail to the laboratory a post-card stating the number of bags used from each bin or their work. Records will be kept at the laboratory and the number

of bags turned in shall be checked up with the original number unloaded into the particular bin.

If an additional precaution is considered necessary by the Engineer in order to insure the use of tested cement only, the following method shall be employed. The sampler shall attach a numbered tag (say) 2 ins. long to each bag of the carload in question. The number shall be the same for the whole carload. When the carload is approved by the laboratory the Inspectors will be given the lot number of the released car. As the cement is used the tags shall be torn off by the Inspectors and at intervals turned in to the laboratory, where they will be counted and recorded.

4. LABORATORY INSPECTION AND TESTS

160. In General. Should the simple field tests (see Sec. 3, page 28), give unsatisfactory or suspicious results, then a full series of tests shall be carefully made by professional inspectors on samples taken from the cement, either at the place of manufacture or on the work, in a manner analogous to that customary among engineers in the purchase of structural steel.

161. Selection of Laboratory. The laboratory shall be selected by or be subject to the approval of the Engineer.

162. Expense of Laboratory Tests. The cost and expense of all inspection and tests shall be borne by the Contractor.

163. Mill Inspection and Sampling. All inspection and sampling shall be made by the Laboratory at the point of manufacture sending samples to its laboratory for tests.

164. Sending Samples to the Laboratory. Samples sent to the testing laboratory shall be preserved in packages which thoroughly protect the cement from the atmosphere. No accurate results consistent with the quality of the cement as it exists in the barrel or bag at the time of sampling will otherwise be possible. Each sample shall be accompanied by a manifest giving complete data of the same.

165. Method of Sampling. Samples shall be taken from different packages of the lot, say from one barrel or bag in every ten. The right shall be reserved, however, to sample any or all packages received. Each sample will be taken with a long

sampling iron reaching to the center of the barrel or bag. (See Sec. 2, page 27.)

166. Quantity of Sample. The quantity of each sample shall be at least eight (8) ounces, or enough to fill a cubical tin box measuring three (3) inches on each edge. (The samples should preferably be put in such boxes, or each may be put in a bag of tough paper, securely tied.)

167. Marking Samples. The several small boxes or bags shall each be plainly numbered and marked with date, and place, and name of structure, and name and address of the party to whom report is to be sent. They shall then be enclosed in a tight box and sent by express, with express charges prepaid, to the testing laboratory, with a separate letter stating that such samples have been sent. Each barrel or bag from which each sample is taken shall also be numbered to agree with the sample numbers.

168. Time of Sending Samples. Samples shall be taken and sent at least two weeks before the time when it is desired to receive report of the result of the tests, in order to allow for time in transit, length of test and mailing of reports of results.

169. Identity of Cement Withheld. The name of the maker of the cement, or its trade-mark, or brand, may be given or omitted, as preferred.

170. Method of Making Tests. Tests, in general, are to be made in accordance with the methods proposed by the Committee on Uniform Tests of Cement of the American Society of Civil Engineers, presented to the society Jan. 21, 1903, and amended Jan. 20, 1904, with all subsequent amendments thereto, except where otherwise noted or required by the Engineer.

171. Visiting Laboratory. Interested parties are at liberty to visit the laboratory and inspect the methods of performing all tests.

172. Cement Tests Required. The completed set of cement tests shall consist of the following:

173. Chemical Test. A chemical analysis of the cement shall account for at least 99 per cent of its component parts.

174. Fineness of Grinding. A test to ascertain the fineness of the cement shall be made by thoroughly sifting about 2 pounds of cement through a covered nest of sieves composed of a No. 50 on top and a No. 100 sieve below, and then weighing the quantities of cement retained on each of the two sieves.

175. Setting Tests of Cement. Setting tests made at the laboratory before and after exposure shall be insisted upon, and if quick setting develops by this additional seasoning the cement shall be rejected.

176. Time of Setting. A test to establish the setting time of cement shall be made by mixing the cement with sufficient water to make a stiff paste and determining the time within which " initial " set shall take place and the limits of time within which " final " or " hard " set must occur.

177. Soundness or Constancy of Volume. All cement must be constant in its volume. The decisive test of this property shall be, that pats of neat cement, made on a glass plate and kept in a damp atmosphere for twenty-four hours, and afterwards immersed in cold water or subjected to the atmosphere of the laboratory, shall not show any signs of warping or cracking at the edges, even after the lapse of a considerable period.

178. Tensile Strength. Tests to ascertain the tensile strength of the cement shall be made both of neat cement and by mixing one part of cement to three parts of sand into briquettes, which are to remain in the molds for twenty-four hours, and then to be placed in water where they are to be kept for twenty-seven days. No record to be taken of briquettes breaking at other than the smallest section.

179. Results of Tests. The results of the tests made in the laboratory shall be accepted as a final criterion for the acceptance or rejection of any particular shipment of cement.

180. Records. Blank forms shall be used for recording all tests and notations shall be adopted to show for each test that the cement passed or failed or that the test was not made. No inference shall be drawn from the lack of any entry other than that the recorder has neglected his duty.

181. Field Inspection. In cases where special conditions make inspection of cement at the place of manufacture impracticable, field or job inspection may be substituted, subject, however, to the approval of the Engineer.

5. MILL INSPECTION AND TESTS

182. In General. The inspection of cement will be made of the works of the cement company, wherever practicable. When so required by the Engineer, the Contractor shall test the cement at the place where the same is being manufactured or stored, and before it is shipped for delivery.

183. Supervision of Tests. The cement shall be tested in the presence of and under the direction of the Engineer or his authorized representative and in accordance with these specifications as interpreted by the Engineer.

184. Access to all Parts of the Mill. The Inspector shall have free access, at all times, to all parts of the mill where material to be inspected by him is being manufactured.

185. Use of Tools, Labor, etc. The Contractor shall furnish all instruments, tools and implements, and all materials and labor required, in the opinion of the Engineer, to satisfactorily carry on such tests. That is to say, the cement manufacturer shall afford the Inspector all facilities and furnish all labor required for taking samples and sealing packages as described below.

186. Compensation for Mill Tests. The Contractor is to claim no compensation for this testing and all that may be required in connection with it, but it is understood and agreed that the price of his bid covers all such testing, which is required to be done at the place of manufacturing or storing before shipment for delivery in accordance with the direction of the Engineer.

187. Character of the Inspection and Tests. Inspection may be personal or of records, or both.

The character and result of each test shall be immediately delivered to the Engineer.

188. Furnishing Inspectors. Whenever required to do so the Contractor must furnish Inspectors who are acceptable to the Engineer for any of the subjects detailed under Scope of Mill Inspection and Scope of Mill Tests.

189. Records to be at the Disposal of the Engineer. All records kept by the manufacturer and which relate to the matters subject to inspection must at all times be at the disposal, both for reference or copy, of the Engineer.

190. Scope of Mill Inspection. Inspection may be required at the discretion of the Engineer of the quantities of the raw material used in the mixture, the preparation of raw material for calcining, the calcining, the selection of clinkers for grinding, the grinding, the storing, the barrels before packing, the barreling, the making of the barrels, the weight of the barrels ready for shipment, and the loading and shipment.

191. Routine of Mill Inspection. The routine of mill inspection will consist of the manufacturer furnishing the cement in bulk or package, at option of the Engineer, in sufficient time and quantities to permit all tests hereinafter specified before the cement will be required for shipment.

192. Scope of Mill Tests. Tests may be required to be made to establish the identity and chemical characteristics of the raw materials used, of the degree of heat reached in calcining, of the chemical characteristics of the finished cement, of the fineness of the cement, the time of setting or setting qualities, its volume constancy or soundness, and of its tensile strength. The tests shall conform to the standard requirements for testing materials.

193. Cement Tests Required. The complete set of cement tests shall consist of the following (see Sec. 4, page 32): Chemical Test, Fineness of Grinding, Time of Setting, Constancy of Volume and Tensile Strength.

194. Test Samples. The cement to be tested at the mill may be taken from the bins before barreling or from the cement after barreling, this being left entirely to the discretion of the Engineer; but the lot from which the cement for testing is taken will be accepted or rejected in accordance as the results of the tests may show that the cement complies with or fails in the requirements of these specifications (see Part VI, page 41), provided, however, that each lot of 100 barrels of cement will be separately tested.

195. Cement Furnished in Bulk. If cement is furnished in bulk, arrangements must be made which will permit of securing a sample satisfactory to the Inspector. Provisions must also be made for sealing the spouts leading to and from the bins sampled.

196. Cement Sampled after being Packed. If the cement is sampled after being packed, each package will be plainly marked by the Inspector for the purpose of identification, and must be so

stored that it will be possible to obtain the packages represented by any one sample without it being necessary to handle others.

197. Setting Aside Special Bins. The cement shall be stored in bins set aside for the use of the City or Owner. In case the manufacturer of cement has not the necessary facilities for setting aside special bins for this purpose until the time of shipment, samples may be taken while the cement is being packed, in which case the packages shall be sealed immediately afterwards.

198. Method of Sampling. When inspected at the place of manufacture, samples shall be taken by the Inspector by means of special tubes driven into the cement. (See Sec. 2, page 28.)

199. Storing, Sampling and Shipping. All details of *storing*, *sampling*, and *shipping* must be such as will meet the approval of the Engineer or Inspector.

200. Preventing Substitutions in Transit. To guard against substitution, the cement shall be loaded for shipment at the mill in the presence of the Inspector and the car sealed by him or the shipment otherwise marked by him in such a manner that any tampering with the individual packages or with the shipment as a whole may be easily detected. Notice of each shipment and a record of all identifying data shall be forwarded to the Engineer or to the Inspector on the job. It will be the duty of the job Inspector to make certain that the shipment as received corresponds in every particular with the description furnished by the mill Inspector.

201. Sealing Packages with a Leaden Seal. When accepted cement is packed ready for shipment each package of cement shall be sealed by the Inspector with a leaden seal for identification. The City or Owner will furnish the leaden seals.

202. Rejection of Accepted Cement. In case cement is accepted on test made on samples taken at the mill, the City or Owner reserves the right to reject the cement on its arrival at the work if it shows any signs of damage from moisture or other causes.

203. Removal of Seal from Rejected Cement. In case packages already sealed are rejected, the seals shall be immediately removed by the manufacturer or owner of the cement when notice of rejection has been received by him.

204. Field Inspection. In cases where special conditions make inspection at factory impracticable, inspection at the job

may be substituted, subject to the approval of the Engineer. (See Sec. 3, Field Inspection and Tests, page 28.)

6. ACCEPTANCE REQUIREMENTS

205. In General. No cement shall be used in the work until it has been accepted by the Engineer. The requirements to be fulfilled by the cement to be furnished under these specifications in order to be acceptable for the construction as evidenced by the results of the inspection tests before described (see Part V, Sec. 4, Laboratory Tests, page 31), are as follows (see Part VI, page 41).

The cement must work well under the trowel; otherwise it will not be accepted.

206. Final Tests. The City or Owner reserves the right to make final tests of the same character and in the same manner as those described for Laboratory Tests, page 31, and Mill Tests, page 34, of all cement delivered on the work, extending to the Contractor all facilities to witness the same.

207. Final Acceptance. If the results of the final tests show that the cement delivered comply with the requirements of these specifications, then the same will be finally accepted by the City or Owner. The acceptance of a cement to be used shall rest with the Engineer, and will be based on the requirements given in Part VI, page 41. The Engineer reserves the right, however, in case there is doubt in his mind as to the suitability of the cement, even though it passes the tests prescribed, to prohibit the Contractor using this cement until it has been further tested and inspected, and has proved entirely satisfactory. The standard tests of acceptance should not, therefore, be taken as a positive criterion that a new grade of cement is satisfactory, but that a known grade is or is not of the average for that particular grade.

208. Rejection of Defective Cement. If any of the cement fails in any of the requirements of these specifications, then the lot of cement which is found wanting will be rejected and the Contractor will be required to move such rejected lot within five days of being notified by the Engineer in writing, from the

property of the City or Owner; provided that all cement delivered shall be passed upon all its requirements in accordance with the results of the tests within 60 days after it has been delivered to the City or Owner, and provided it shall be passed upon in lots of not more than 100 barrels. In other words, if any lot of cement, as determined by a reasonable number of samples, fails to pass the tests, or is otherwise unsuitable for use in the work, the entire lot from which the samples were taken shall be rejected and immediately removed from the works.

209. Additional Requirements and Modifications. All cement shall meet such additional requirements as to "hot water," "set," and "chemical," tests, as the Engineer may determine. The requirements for "set" may be modified where the conditions are such as to make it advisable. In other words, in addition to the specified tests, all cement furnished for the work shall be subject to such other tests as may be necessary to determine whether the cement passes the proper qualities for the particular work for which it is designated.

209a. Three-day Tests. In case sufficient time is not available within which to make the seven- and twenty-eight-day tests, a test shall be made at the end of three (3) days and for comparison will be used in connection with the twenty-four (24) hour and seven (7) day tests.

210. Boiling-water Test. The acceptance or rejection of cement where it is to be used within four (4) days after receiving may be based chiefly on the results of the accelerated tests (see page 42), and it is required that the pats shall remain firm and hard and show no signs of distortion, checking or disintegration. (It is often good policy before rejecting a cement which fails to pass the boiling test to hold it for a week or two so that it may further season and then retest it.)

211. Exposure to Moisture. Any cement exposed to moisture after inspection shall not be used. That is to say, no cement shall be used that has absorbed sufficient moisture to cause the cement to granulate or become lumpy when thoroughly dried.

212. Reinspection, Test and Rejection. Cement shall be subjected to reinspection, test and rejection, if necessary, at any time. In case any lot of cement fails in one or more of the specified requirements, it shall be given a second test for such requirement or requirements, which test shall be final and binding.

213. Extended Tests. The rejection or acceptance of cement will ordinarily be done after the completion of the seven-day test, but it shall be optional with the Engineer to demand the completion of the twenty-eight-day tests before passing upon the acceptance of the cement. The Engineer may, however, direct that tests be made, from time to time, of tensile strength and soundness, extending over longer periods than twenty-eight days; if cement so tested shows a reduction of strength with increased age, or at any time fails in respect to soundness, the Engineer may prohibit the future use of that brand of cement and require that another brand be substituted.

213a. Strength of Cement at Three-Months' Intervals. The tensile strength of both neat and sand briquettes shall show a satisfactory increase of strength up to periods of one year. The Contractor shall, if required, finish previously obtained evidences of the strength of the cement at periods of three, six, nine and twelve months.

214. Tagging Accepted Cement. Each package of cement, after its acceptance by the Engineer, must bear an acceptance tag or label, to be fixed by the Engineer to each lot which has satisfactorily passed all the tests which he desires. The Contractor shall carefully preserve these marks and not allow them to be imitated. As the accepted cement is removed from the storehouse for use in the work, the tags or labels must be removed or destroyed by the Engineer or the Inspector.

215. Rejection of Accepted Cement. Should the Engineer at any time claim any lot of cement damaged or questionable in any respect, the same shall be rejected, although it may previously have met other tests. Marked deviation from uniform or characteristic results in tests may be considered cause for rejection of any lot of cement, even though the test requirements may otherwise be fulfilled. In other words, uniformity in quality is essential in any grade of cement, and any cement which fails to give uniform results under uniform and approved treatment shall be rejected even if it complies with the specifications in other respects or it may be withheld from use until more extended tests shall have demonstrated its reliability.

216. Acceptance or Rejection Requirements. Cement of each brand shall be required to show uniform and characteristic results in tests. The acceptance or rejection of cement used under

these specifications shall be based on the following requirements:

(*a*) Fineness of Grinding. (Pars. 226, 237, 244.)
(*b*) Specific Gravity. (Pars. 227, 238, 245.)
(*c*) Time of Setting. (Pars. 228, 239, 246, 256, 259.)
(*d*) Tensile Strength. (Pars. 229, 240, 247, 257, 260.)
(*e*) Constancy of Volume. (Pars. 231, 241, 248.)
(*f*) Chemical Composition. (Par. 233.)
(*g*) Microscopic Test. (Par. 234.)

PART VI

TEST REQUIREMENTS FOR CEMENT

1. GENERAL REQUIREMENTS

217. In General. All tests shall be made in accordance with the methods proposed by the Committee on Uniform Tests of Cement of the American Society of Civil Engineers, presented to the Society January 21, 1903, and amended January 20, 1904, and January 14, 1908, with all subsequent amendments thereto.

218. Experienced Testers. Acceptance or rejection under these specifications shall be based on tests made by a person experienced in cement testing and having the proper means for making the tests.

219. Fineness. The sieves must be kept thoroughly dry. In each of the following requirements (see Sec. 2, 3 and 4), it is assumed that thoroughly dried sieves are used.

220. Specific Gravity. Specific gravity of cement may be used as an aid in detecting adulteration or underburning, but it is not necessarily conclusive as an indication of the quality of a cement.

221. Time of Setting or Setting Qualities. The following requirements cover the time within which " initial " set shall take place and the limits of time within which " final " or " hard " set must occur. Slow-setting cements should not materially increase in temperature during setting, whereas with quick-setting cements a marked increase is permissible.

222. Tensile Strength. The time of set must be stated when specifying the tensile strength required. Tensile tests will be made on specimens prepared and maintained until tested at a temperature of not less than 60° F. Each specimen will have an area of 1 sq.in. at the breaking section, and after being allowed to harden in moist air for 24 hours will be immersed and maintained under water until tested. All test pieces must be tested immediately after being taken out of water. Cement which

shows abnormally high strength on the one-day or seven-day tests may be regarded as unreliable, and may be rejected therefor.

223. Seven-day Tests. Cement must not be used unless it has satisfactorily passed the seven-day tests, but in case of failure it may be held for the result of the twenty-eight-day tests before being finally accepted or rejected.

224. Constancy of Volume. Cement shall have the same constancy of volume in air as under water. Hence it must be tested under both conditions, except for Puzzolan cement, which must be tested for soundness under water. Tests shall therefore be made on at least two pats or cakes of neat cement, prepared on a glass plate and kept in a damp atmosphere for twenty-four hours, and afterwards one of the pats immersed in water and the other kept in air at normal temperature.

224a. Boiling-water Test. Should the sample fail to pass the hot-water test, the Engineer reserves the right to reject the lot or to order a retest, or to subject the sample to chemical analysis in order to determine whether said failure to pass the hot-water test was occasioned by free lime or other deleterious conditions. The Engineer may withhold his approval until after the result of the twenty-eight-day test of the cake in cold water can be observed, or he may order a new boiling test from new samples drawn from the same lot, but from different packages. If the twenty-eight-day cold-water test or the second boiling test is unsatisfactory, the lot must be rejected.

2. PORTLAND CEMENT

225. Definition. Portland cement shall be defined as the finely pulverized product, resulting from the calcination to incipient fusion of an intimate mixture of properly proportioned argillaceous and calcareous materials, and to which no addition of other material greater than three per cent (3%) has been made subsequently to calcination. No slag, Puzzolan, sand nor mixed cements will be accepted under this classification. In other words, the cement shall be manufactured of a mixture of argillaceous and calcareous material in definite proportions and shall contain no furnace slag, gray limestone, hydraulic lime or trash.

226. Fineness of Grinding. All cement shall be finely ground, so that 100% shall be passed through a sieve of 20 x 20 meshes per square inch.

At least 99% shall pass through a sieve of 50 x 50 meshes per square inch.

At least 92% shall pass through a sieve of 100 x 100 meshes per square inch.

At least 75% shall pass through a sieve of 200 x 200 meshes per square inch.

227. Specific Gravity. The specific gravity of the cement, thoroughly dried at 100° C., shall not be less than three and ten one-hundredths (3.10), preferably between 3.12 and 3.25.

228. Time of Setting. The time of setting shall be determined with neat cement paste of normal consistency by the Vicat needle. The setting shall not commence before thirty (30) minutes, nor terminate in less than one (1) hour nor more than ten (10) hours. For slow-setting cement, the initial set must occur in not less than one hour.

229. Tensile Strength. Briquettes one (1) square inch in cross-section, made of normal consistency and kept twenty-four (24) hours in moist air, and the remaining time in water at normal temperature, +70° F., shall show at least the following strength as determined from an average of five specimens:

(*a*) *Neat Cement*

AGE	STRENGTH *
24 hours in moist air	175 lbs.
7 days (1 day in moist air, 6 days in water)	450 lbs.
28 days (1 day in moist air, 27 days in water)	550 lbs.

(*b*) *One Part Cement, Three Parts Standard Sand*

AGE	STRENGTH *
7 days (1 day in moist air, 6 days in water)	150 lbs.
28 days (1 day in moist air, 27 days in water)	250 lbs.

(*c*) *One Part Cement, Three Parts Sand*

AGE	STRENGTH
7 days (1 day in moist air, 6 days in water)	110 lbs.
28 days (1 day in moist air, 27 days in water)	180 lbs.

* The American Society for Testing Materials gives minimum requirements as follows: Neat Cement, 24 hours, 150–200 lbs.; 7 days, 450–550 lbs.;

The sand for test (*b*) shall be standard quartz sand, which shall pass a 20 x 20 mesh sieve and be retained on a 30 x 30 mesh sieve.

The sand for test (*c*) shall be taken by the Engineer from that used on the work and is intended as a test of the mortar.

230. Failure of Briquettes to Pass Tests. Should the briquettes from a slow-setting cement fail, by a slight amount, to pass the twenty-four (24) hour or seven (7) day requirements for neat cement only, the lot in question will be held awaiting the results of the twenty-eight (28) day briquettes. Should the results of the seven (7) day tests on both neat and mortar briquettes fall below the requirements stated herein, the shipment will be rejected. If the strength of the twenty-eight (28) day mortar briquettes on a lot held awaiting the results of the twenty-eight (28) day neat briquettes does not show at least a ten per cent (10%) increase over the strength shown by the seven (7) day mortar briquettes, the lot will be rejected, even if the briquettes show a strength as herein required.

231. Constancy of Volume or Soundness. Circular pats of neat cement paste three (3) inches in diameter, one-half ($\frac{1}{2}$) inch thick at the center and tapering to a thin edge, shall be kept in moist air for twenty-four (24) hours.

(*a*) A pat shall be kept in air at normal temperature for twenty-eight (28) days.

(*b*) Another pat shall be kept in water maintained as near 70° F., as practicable for twenty-eight (28) days.

(*c*) A third pat shall be exposed to steam above boiling water in a loosely closed vessel for five (5) hours.

To pass the requirements, these pats shall remain firm and hard, and show no signs of distortion, checking, cracking, discoloration or disintegration.

232. Failure of Pats to Pass Tests for Soundness. In case the pats exposed to steam, on a lot of cement otherwise satisfactory, show signs of failure, two more pats shall be made. If one of the extra pats fails after exposure to steam the lot will be held for twenty-eight (28) days and resampled. If both

28 days, 550–650 lbs.; 1:3 mortar, 7 days, 150–200 lbs.; 28 days, 200–300 lbs.; the exact values to be fixed in each case by the consumer. If no minimum strength is specified the mean of these values is to be taken as the minimum strength required.

of the additional pats are sound the lot may be accepted. In case a lot is held for resampling at the end of twenty-eight (28) days because of failure of the steam pats, the lot must pass every requirement on the second sampling or it will be immediately rejected.

In case the normal pats on a lot of cement held awaiting the results of the twenty-eight (28) day briquettes show signs of disintegration, the lot will be rejected, even if it passes the other requirements.

233. Chemical Composition. The cement shall not contain more than one and seventy-five one-hundredths per cent (1.75%) of sulphuric anhydride or anhydrous sulphuric acid (SO_3), nor more than four per cent (4%) of magnesia (MgO). It shall also contain no adulteration nor excess of ingredients which, in the opinion of the Engineer, shall render it unfit for use in the work.

The chemical composition of the cement shall also be within the following limits:

Silica, 21 to 24%.
Alumina, 5 to 10%.
Iron oxide, 2 to 4%.
Lime, 60 to 65%.
Alkalies, not more than 3%.
Clay, 5 to 8%.
Loss by calcination, carbonic acid and water, not more than 2½%.

But in certain cases where such amounts of these substances are objectionable the Engineer may specify lower percentages.

The cement shall not contain an excess of free lime.

234. Microscopic Test. The cement shall show no signs of the presence of detrimental amount uncombined magnesia as indicated by the microscopic test.

235. Color. The color shall be a uniform bluish gray, free from yellow or brown particles. Yellow checks or places indicate an excess of clay or that the cement has not been sufficiently burned; and it is then probably a quick-setting cement of low specific gravity and deficient strength.

3. NATURAL CEMENT

236. Definition. Natural cement is a finely pulverized product resulting from the calcination of limestone containing clay and carbonate of magnesia at a temperature only sufficient to drive off the carbonic acid gas. That is to say, by natural cement is meant one made by calcining natural rock at a heat below incipient fusion and grinding the product to powder. No slag, Puzzolan, nor sand cement, will be accepted under this classification.

237. Fineness of Grinding. Cement shall be finely ground, so that not more than ten per cent (10%) by weight shall remain on a sieve of 100 meshes per lineal inch, made of No. 40 wire, Stubbs' gage, and thirty per cent (30%) on a sieve of 200 meshes per lineal inch.

238. Specific Gravity. The specific gravity of the cement, thoroughly dried at 100° C., shall not be less than two and eight-tenths (2.8).

239. Time of Setting. The time of "initial set" shall not occur in less than ten (10) minutes, and it shall reach its "final or hard set" in not less than thirty (30) minutes, or in more than three (3) hours. The time of setting shall be determined by means of the Vicat needle from pastes of neat cement of normal consistency, the temperature being between 60 and 70° F.

240. Tensile Strength. Briquettes of cement, with one (1) square inch of cross-section, shall develop the following ultimate tensile strength as determined from an average of five specimens.

Neat Cement

AGE	STRENGTH *
24 hours in moist air	75 lbs.
7 days (1 day in moist air, 6 days in water)	150 lbs.
28 days (1 day in moist air, 27 days in water)	250 lbs.

One Part Cement, Two Parts Standard Sand

AGE	STRENGTH
7 days (1 day in moist air, 6 days in water)	120 lbs.
28 days (1 day in moist air, 27 days in water)	175 lbs.

* The American Society for Testing Materials gives minimum requirements as follows: Neat Cement, 24 hours, 50–100 lbs.; 7 days, 100–200 lbs.; 28 days,

One Part Cement, Three Parts Standard Sand

AGE	STRENGTH *
7 days (1 day in moist air, 6 days in water).....	50 lbs.
28 days (1 day in moist air, 27 days in water).....	110 lbs.

For all tests with sand, standard quartz sand, which will pass a No. 20 sieve and remain on a No. 30 sieve, shall be used.

241. Constancy of Volume or Soundness. Circular pats of neat cement paste three (3) inches in diameter, one-half ($\frac{1}{2}$) inch thick at the center and tapering to a thin edge, shall be kept in moist air for twenty-four (24) hours.

(*a*) A pat shall be kept in air at normal temperature for twenty-eight (28) days.

(*b*) Another pat shall be kept in water maintained as near 70° F. as practicable for twenty-eight (28) days.

These pats shall remain firm and hard, and show no signs of distortion, checking, cracking, discoloration or disintegration after twenty-eight (28) days in either air or water.

242. Boiling Test. A boiling test may also, at the option of the Engineer, be required, to be made by mixing pats as above, placing them at once in cold water, raising the temperature of the water to boiling in about an hour, continuing boiling for three hours, then examining for checking and softening.

4. PUZZOLAN OR SLAG CEMENT

243. Definition. This term shall be applied to the finely pulverized product made by grinding together without subsequent calcination granulated blast-furnace slag with slacked lime. Although often sold under the name of Portland cement and available for many of the same processes, it is not a true Portland cement according to the accepted definitions.

244. Fineness of Grinding. Cement must be finely ground, so that at least ninety-seven per cent (97%) shall pass through a sieve of 100 x 100 meshes per square inch made of No. 40 wire, Stubbs' gauge.

200-300 lbs., 1:3 mortar, 7 days, 25–75 lbs.; 28 days, 75–150 lbs., the exact values to be fixed in each case by the consumer. If no minimum strength is specified the mean of these values is to be taken as the minimum strength required.

245. Specific Gravity. The specific gravity of the cement, thoroughly dried at 100° C., shall be between 2.7 and 2.8.

246. Time of Setting. The time of "initial set" shall not occur in less than forty-five (45) minutes, and shall acquire its "final set" in ten (10) hours. The time of setting shall be determined by means of the Vicat needle from pastes of neat cement of normal consistency, the temperature being between 60 and 70° F.

247. Tensile Strength. Briquettes of cement, with one (1) square inch of cross-section, shall develop the following ultimate tensile strength as determined from an average of five specimens.

Neat Cement

AGE	STRENGTH
7 days (1 day in moist air, 6 days in water).....	350 lbs.
28 days (1 day in moist air, 27 days in water).....	500 lbs.

One Part Cement, Three Parts Standard Sand

AGE	STRENGTH
7 days (1 day in moist air, 6 days in water).....	130 lbs.
28 days (1 day in moist air, 27 days in water).....	220 lbs.

For all tests with sand, standard quartz sand, which will pass a No. 20 sieve and remain on a No. 30 sieve, shall be used.

248. Constancy of Volume or Soundness. Circular pats of neat cement paste three (3) inches in diameter, one-half ($\frac{1}{2}$) inch thick at the center and tapering to a thin edge, placed on a glass plate, shall not show any signs of warping or cracking after twenty-eight (28) days in water.

249. Weight. The average weight per barrel shall not be less than 330 pounds net. Four sacks shall contain one barrel of cement.

5. SILICA CEMENT OR SAND CEMENT

250. Definition. Silica cement or sand cement is a finely pulverized product resulting from the grinding together of silica or clean sand and Portland cement.

251. Test Requirements. In all cases, the cement from which the product is made shall be tested precisely as other cement.

6. ADDITIONAL REQUIREMENTS

252. In General. Further requirements that the Engineer may deem necessary, or any modification of the tests herein given, in order to secure the best grades of cement that are upon the markets, will be made and said additions and modifications are hereby made a part of these specifications and binding upon the Contractor.

253. Time of Setting. The requirements for setting, as above stated, may be modified where the conditions of the work are such as to make it advisable, and the manufacturer of the cement will be notified of such change in time of setting to meet those special requirements.

254. Briquettes Subjected to Boiling Test. If so required by the Engineer, pieces of briquettes broken in tension tests of Portland cement, either neat or mortar, must remain hard and sound after the same exposure to steam or boiling water as specified for the pats or cakes.

7. SPECIAL REQUIREMENTS (QUICK-SETTING PORTLAND CEMENT)

255. In General. Where required for pipe joints or elsewhere the Engineer may require a quick-setting Portland cement which shall meet the following special requirements, all other requirements being the same as for ordinary Portland cement (see Sec. 2, page 42).

256. Time of Setting. It shall require not less than fifteen (15) minutes nor more than thirty (30) minutes to develop initial set and not over one (1) hour and thirty (30) minutes to develop final set under the normal conditions as prescribed above.

257. Tensile Strength. Tensile strength of neat cement shall be not less than

24 hours (in water after hard set)	100 lbs. per sq.in.
7 days (1 day in air, 6 days in water)	300 lbs. per sq.in.
28 days (1 day in air, 27 days in water)	450 lbs. per sq.in.

8. CEMENT USED IN SEA WATER

258. In General. When cement is intended for concrete to be deposited under water it shall be first subjected to the following test:

259. Setting Qualities. Mix a small batch (about one cubic foot) of concrete of the proportion to be used in the work, and deposit it in a barrel of the water in which the proposed structure is to be built. If the concrete does not " set up " in a manner satisfactory to the Engineer the cement shall be rejected.

260. Testing Briquettes. Briquettes left in molds and placed in water immediately after mixing must harden to the satisfaction of the Engineer, so as to prove the fitness of the cement for setting under water. This test may be made a comparative one by pitting the cement tested against brands of established reputation. Any cement not hardening under water to the entire satisfaction of the Engineer will be rejected.

PART VII

METHODS OF TESTING CEMENT

1. GENERAL REQUIREMENTS

261. In General. The methods proposed by the Committee on Uniform Tests of Cement of the American Society of Civil Engineers, presented to the society Jan. 21, 1903, and amended Jan. 20, 1904, with all subsequent amendments thereto, shall be employed, unless otherwise specified by the Engineer.

262. Sampling Cement. The sampling should depend upon the purpose for which the tests are made, and upon the previous tests that have been made with the same cement. Samples should be taken from different packages of each shipment, and as near as possible out of the middle of the barrel or bag. (See Part V, Sec. 2, page 27.)

263. Screening Samples. All samples should be passed through a sieve having twenty meshes per lineal inch in order to break up lumps and remove foreign material.

264. Temperature. All experiments shall be carried on, as nearly as possible, at a uniform temperature of 65° F., except when tests are being made for the purpose of ascertaining the comparative strength of cements required for winter use. That is to say, tests of cement will, unless otherwise specified, be made at a temperature of from 60 to 70° F. The temperature of the water and of the room in which the test pieces are made and tested should not be permitted to fall below 60° F.

265. Proportions. All proportions shall be determined by weight.

266. Water. Ordinary fresh, clean water having a temperature between 60 and 70° F., shall be used for the mixture and immersion of all test pieces or samples, unless the nature of the tests require that sea water be employed.

267. Record of Tests. The temperature of the air and of the water used in mixing should be noted in the record of tests. The relative humidity of the air should also be observed and recorded. In every case the quantity of water used in mixing shall be stated in the report.

2. CHEMICAL ANALYSIS

268. In General. Chemical tests may be applied at the discretion of the Engineer, and shall pass the same to his satisfaction. All of the elements found should be indicated, without grouping, in the record of proceedings of the operation.

269. Method. As a method to be followed for the analysis of cement, that proposed by the Committee on Uniformity in the Analysis of Materials for the Portland Cement Industry, of the New York Section of the Society for Chemical Industry, and published in *Engineering News*, Vol. 50, p. 60, 1903; and in *The Engineering Record*, Vol. 48, p. 49, 1903, shall be followed. (See Part IX, page 77.) Methods should be left to the chemist.

3. FINENESS

270. In General. The degree of pulverization of the cement shall be ascertained by measuring the residue retained on certain sieves. Those known as No. 100 and No. 200 sieves shall be used for this purpose.

All kinds of cement should be treated alike in the shaking process.

271. Sieves. The sieves should be circular, about 20 cm. (7.87 in.) in diameter, 6 cm. (2.36 in.) high, and provided with a pan 5 cm. (1.97 in.) deep, and a cover.

The sieves shall be of brass wire having the following diameters: No. 100, 0.0045 in.; No. 200, 0.0020 in.

The brass wire shall be mounted on the frames without distortion. The mesh shall be regular in spacing and be within the following limits: No. 100, 96 to 100 meshes to the linear inch; No. 200, 190 to 200 meshes to the linear inch.

272. Amount of Cement to be Used. One hundred (100) grams (3.52 oz.) shall be used for each determination, the sample being carefully dried at a temperature of 100° C. (212° F.) prior to sieving.

273. Hand Sieving. The thoroughly dried and coarsely screened sample of cement shall be weighed and placed on the No. 200 sieve, which, with pan and cover attached, shall be held in one hand in a slightly inclined position, and moved forward and backward, at the same time striking the side gently with the palm of the other hand, at the rate of about 200 strokes per minute. The operation shall be continued until not more than one-tenth of 1% passes through after one minute of continuous sieving. The residue shall then be weighed, and placed on the No. 100 sieve and the operation repeated. Some specifications require that the shaking be continued until no cement is seen to fall upon a sheet of white paper held below the sieve. In other words, the shaking should continue until no more passes through.

274. Mechanical Sifter. A mechanical sifter, working automatically by jig motion, may be used instead of hand sieving.

275. Examination of Sieves. The sieves shall be freqeuntly examined, magnified, if practicable, to see that no wires are displaced, leaving apertures larger than the normal.

276. Use of Shot or Small Weights. The introduction of small weights or of large shot into the cement, while being sifted, is to be deprecated, as they tend to push an undue proportion of the cement through the mesh, to stretch the wires and to increase the grinding. (The Committee of the Am. Soc. Civ. Engrs. recommends hands ifting with a small quantity of large shot in the sieve).

277. Percentage of Fineness. The weight of the material passing the sieve plus the weight of the dust lost in air, expressed in hundredths of the original weight, will express the percentage of fineness. In order to determine this percentage the residue on the sieve must be weighed. The results should be reported to the nearest tenth of 1 per cent.

4. SPECIFIC GRAVITY

278. In General. The sample will be carefully dried before the determination is made. Inasmuch as the differences in specific gravity are usually very small, great care must be exercised in making the determination. The determination of specific gravity shall be made on the cement as received; and should it fall below the standard required in the specifications, a second determination will be made on the sample ignited at a low red heat. It cannot be too strongly emphazised that special care must be exercised in specific gravity tests.

279. Temperature. The standard temperature for specific gravity determinations is 62° F., but for cement testing temperatures may vary between 60 and 80° F., without affecting results more than the probable error in the observation.

280. Apparatus. Any approved form of volumenometer or specific gravity bottle, graduated to cubic centimeters with

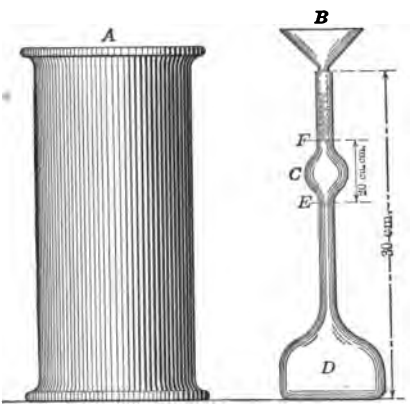


FIG. 1.—Le Chatelier's Specific Gravity Apparatus.

decimal subdivisions, may be used. The Le Chatelier apparatus will be accepted as satisfactory and is the one recommended by the Committee of the American Society of Civil Engineers. (See Fig. 1.) Accurate results may be obtained with the picnometer.

281. Benzine or Kerosene. Benzine (62° Baumé naphtha), or kerosene free from water, should be used in making the determination.

282. Determination of Specific Gravity. Fill the specific gravity bottle to zero of the scale with benzine, turpentine, or some other liquid having no action upon cement. Take 100 grams of sifted cement that has been previously dried by exposure on a metal plate for twenty (20) minutes to a dry heat of 212° F., and allow it to pass slowly into the fluid of the specific gravity bottle, taking care that the powder does not stick to the sides of the graduated tube above the liquid and the funnel through which it is introduced does not touch the fluid. The volume of the displaced liquid is then carefully read to the nearest fraction of a cubic centimeter.

The specific gravity is then obtained by dividing 100 grams by the displacement in cubic centimeters, or may be expressed by the formula:

$$\text{Specific gravity} = \frac{\text{Weight of cement, in grams,}}{\text{Displaced volume, in cubic centimeters}}.$$

The specific gravity bottle, during the operation, shall be kept immersed in water in a jar, in order to avoid variations in the temperature of the liquid.

283. Results. The results shall agree within 0.01.

5. NORMAL CONSISTENCY

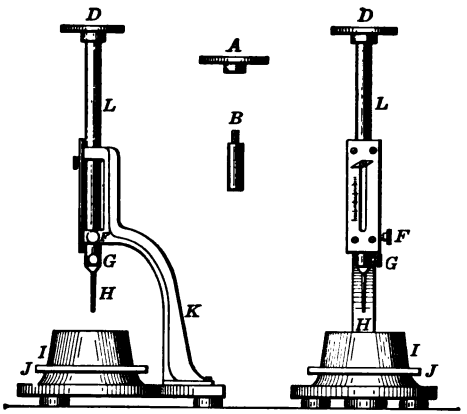
284. In General. In performing the tests for tensile strength, soundness, time of setting and temperature, the cement will be mixed with sufficient water to produce a semi-plastic mass of normal consistency. The determination of the proper percentage of water to be used in making pastes from which pats, tests of setting, briquettes, etc., are made, will consist in measuring the amount of water required to reduce the cement to a given state of plasticity, or what is usually called the normal consistency.

285. Apparatus. For the purpose of determining the normal consistency of a mixture of cement and water or a mixture of cement, sand and water, the Vicat needle recommended by the Committee of the American Society of Civil Engineers, should be used. (See Fig. 2.)

286. Determining the Normal Consistency. The paste shall be considered to be of normal consistency when the cylinder of the Vicat needle, weighing 300 g. (10.58 oz.) penetrates to a

point in the mass 10 mm. (0.39 in.) below the top of the ring or the level of the paste, great care being taken to fill the ring exactly to the top. The trial pastes shall be made with varying percentages of water until the correct consistency is obtained.

287. Simple Method. A simpler method for determining the normal consistency for neat cement tests is to mold a ball of mortar in the hands to a plastic state and drop the same about 20 inches on the table. If the ball neither flattens appreciably nor cracks, the consistency is satisfactory. This process corresponds practically with the previous method. If dropped



VICAT NEEDLE.

FIG. 2.

20 inches from a metal trowel, the paste shall leave the trowel clean. Light pressure should bring water to the surface and the paste should not stick to the hand.

6. TIME OF SETTING OR SETTING QUALITIES

288. In General. This test will consist in determining the time which elapses from the moment water is added until the neat cement paste ceases to be fluid and plastic (called the "initial set"), and also the time required for the paste to acquire a certain degree of hardness (called the "final" or "hard set"). This test should be made only on neat cement.

289. Vicat Needle. The time of setting may be determined with neat cement paste of normal consistency by the Vicat needle

recommended by the Committee of the American Society of Civil Engineers. (See Fig. 2.)

290. Gilmore Needles. The time of setting may also be determined by the Gilmore needles, consisting of weighted wires of given diameter as follows; one-twelfth ($\frac{1}{12}$) of an inch in diameter weighted to one-fourth ($\frac{1}{4}$) of a pound and the other needle one twenty-fourth ($\frac{1}{24}$) of an inch in diameter weighted to one (1) pound.

291. Amount of Water. These specifications contemplate a temperature varying not more than 10° from 62° F., and quantities of water given herein:

For Portland cement use 20 per cent of water.

For Natural cement use 30 per cent of water.

For Puzzolan cement use 18 per cent of water.

292. Sifting Cement. The cement that is to be made in pats or cakes should not be sifted, but it is to be used exactly as it comes from the barrels or bags.

293. Mixing the Paste. The test for the determination of the time set of the cement will be made by mixing thoroughly the required proportions of cement and water for five minutes, vigorously rubbing the mixture under pressure; time to be estimated from the moment of adding water. Some specifications require that a quick-setting cement be stirred one minute and a slow-setting one three minutes, using sufficient water to make a stiff paste.

294. Molding. Two pats or cakes from the above mixture shall be molded on glass plates, about three (3) inches in diameter and one-half ($\frac{1}{2}$) inch thick at middle and drawn to thin edges. The test pats or cakes should be made by rolling the cement into balls and then flattening.

295. Storage of Test Pieces. The test pieces shall be stored in moist air as soon as made, and there remain during the test. This shall be accomplished by placing the test pieces on a rack over water contained in a pan and covered with a damp cloth, the cloth to be kept away from them by means of a wire screen; or they shall be stored in a tight box not exposed to currents of dry air, i.e., a moist closet.

296. Method of Testing. At the end of the time specified for " initial " set apply the needle one-twelfth of an inch diameter weighted to one-fourth of a pound to one of the pats. If an

indentation is made the cement passes the requirement for initial setting, if no indentation is made by the needle the cement is too quick setting. At the end of the time specified for " final set " apply the needle one twenty-fourth of an inch diameter weighted to one pound. The cement should not be indented.

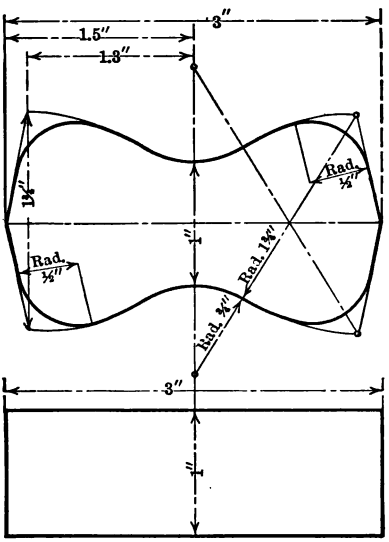
Initial set shall mean that the pat supports $\frac{1}{4}$ of a pound on a wire $\frac{1}{12}$ inch in diameter, and final set that it supports one pound on a wire $\frac{1}{24}$ inch in diameter, without indentation.

7. BRIQUETTE MAKING

(a) *General Requirements*

297. In General. Briquettes for testing strength of cement will be made both of neat cement and sand in the proportions hereinafter specified.

298. Form of Briquette. The form of briquette used for tensile strength determination will be in accordance with the



DETAILS FOR BRIQUETTE.

FIG. 3.

American Society of Civil Engineer's Standard, which is in the shape of the figure 8, having a cross-section of one (1) square inch in the middle. (See Fig. 3.)

299. Number of Briquettes. Four briquettes are about the maximum number that may be made well within the time generally required for initial setting of moderately slow-setting cements.

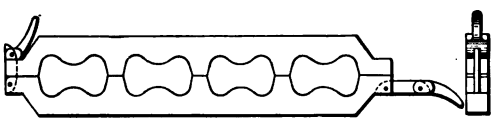
300. Consistency of Mixture. Enough water only shall be added to thoroughly moisten the mixture and make it coherent. That is to say, all cement for test briquettes will be mixed with barely sufficient water to make a stiff dough or mortar, which will be forced into the mold by pressure or tamping, so as to give as nearly as possible the density of good concrete work, Mixtures that at first appear too dry for testing purposes may be rendered more plastic under prolonged working. The consistency should be such that the briquette, after a certain degree of working, exudes some mortar on its top surface.

301. Proportions. All proportions should be stated by weight; the quantity of water to be used shall be stated as a percentage of the dry material. In preparing briquettes for test, sufficient material is to be taken to make one batch of four briquettes at a time, and enough water added to make a stiff paste as above stated.

302. Sifting Cement. The cement that is to be made in briquettes should not be sifted, but it should be used exactly as it comes from the barrels or bags.

303. Mixing. The mixing for briquettes is best done by a large spoon in a bowl, by a trowel on a table, or by a machine. The mixing must be uniform.

304. Molds. The briquettes are to be formed in suitable molds. The molds shall be made of brass, bronze, or some



DETAILS FOR GANG MOULD.

FIG. 4.

equally non-corrodible material, having sufficient metal in the sides to prevent spreading during molding. Gang molds, which permit molding four briquettes at one time, are recommended by the Committee of the American of Civil Engineers as shown in Fig. 4.

305. Molding. The molds in which the briquettes are allowed to set should be placed on a table of marble or polished metal, (without blotting paper), or rest directly on glass, slate, or other non-absorbent material. Both molds and slab should be well cleaned, and rubbed over with a greasy cloth.

306. Böhme Hammer Apparatus. Both the neat and mortar briquettes may be prepared by the Böhme Hammer Apparatus, which is a tilt hammer with automatic action. The hammer is driven by a cam wheel of ten cams actuated by a simple gearing. The steel hammer weighs about $4\frac{1}{2}$ lbs., and when the intended number of blows has been delivered the mechanism is automatically checked, the proper setting having been made for this purpose before beginning the work. The number of blows for each briquette should be 150.

The hammer apparatus of Böhme for making briquettes removes all variability in their preparation and is to be recommended on account of its ease of operation and its uniformity. Many years of experience, especially in Germany, with this apparatus have given very satisfactory results.

307. Removing Briquettes. Considerable care must be exercised in removing briquettes before hard-set. After loosening the latch of the mold, tap gently the sides of the mold until they fall apart. The briquettes should be placed face down in water tank or pan.

308. Weighing Briquettes. Briquettes shall be weighed after taking them out of the molds so as to be assured of the regularity of their manufacture and those which vary in weight more than 3 per cent from the average shall not be tested.

309. Storage of Briquettes. All briquettes shall be kept one day in damp air, and submerged in clean water for the remainder of the time. (See Sec. 8, page 63.)

(*b*) *Neat Briquettes*

310. In General. Neat briquettes will be made by mixing with the cement the least quantity of water necessary to form a stiff plastic mass, and the same thoroughly kneaded.

311. Number of Neat Briquettes. At least one batch of four briquettes each of neat cement shall be made, one briquette being broken at seven (7) and twenty-eight (28) days, giving one test at each period.

312. Amount of Water. Enough water shall be used to insure a homogeneous briquette, but not enough to cause the cement to swell the above level of the mold, or free water to flow to the surface when smoothed off with a trowel.

For neat tests of Portland cement use 20 per cent of water by weight.

For neat tests of Natural cement use 30 per cent of water by weight.

For neat tests of Puzzolan cement use 18 per cent of water by weight.

313. Molding. The molds shall be filled two-thirds full with the plastic mass and the cement pressed in with the thumbs; then filled completely, thumbed again, and leveled off smoothly even with the top of the mold. The mold will then be turned over, the cement thumbed once and finished level as directed for the first side. In other words, the cement paste for making neat tests shall be pressed into the mold with the fingers, care being taken to work out all air bubbles. The excess paste at top of mold shall be removed with a sharp blade, and top of briquette smoothed with trowel. Adding cement paste after once the molds have been filled shall not be allowed. The briquette should always be finished on both sides with the trowel.

(c) *Sand Briquettes*

314. In General. Sand briquettes will be made by mixing with the cement the required proportions of sand, and only enough water added to thoroughly moisten the mixture and make it coherent.

315. Number of Sand Briquettes. At least three (3) batches of four briquettes each of sand mixtures shall be made, one briquette of each batch being broken at seven (7) day and twenty-eight (28) days, giving three tests at each period.

316. Proportions. The proportions of cement and sand and water shall in all cases be carefully determined by weight, not guessed at as is too frequently the case.

317. Sand. The sand used in test shall be clean, coarse, and dry, and be such as shall pass a No. 20 sieve (400 meshes per square inch, wire to be No. 28 Stubbs' wire gauge), and to be retained on a No. 30 sieve (900 meshes per square inch, wire to

be No. 31 Stubbs' gauge). It should be the best quality obtainable of washed river sand.

317a. Standard Sand. For purposes of comparison, a special sand has been selected by scientists and called the "Standard Sand." It may be obtained from all large testing laboratories and many cement manufacturers. Results obtained with it, however, are usually much below those obtainable with commercial sands.

318. Amount of Water. Just enough water shall be used to form a homogeneous dense briquette without showing a tendency for the cement or water to draw to the surface when finished with a trowel.

Portland cement requires water from 10 to 12½ per cent by weight of constituent sand and cement for maximum strength in tested briquettes.

Natural, about 15 to 17 per cent.

Puzzolan, about 9 to 10 per cent.

319. Mixing. The cement and sand in proper proportions shall be mixed dry and nearly all the water specified above added at once, the remainder as needed, and mix for five minutes by triturating or rubbing together the constituents of the mortar. This may be done by rubbing between the fingers, using rubber gloves for protection, or under pressure with a trowel. The mixing is to be done as rapidly as possible to secure a thorough mixture of the materials. Five minutes is the time of mixing quite generally adopted in European specifications for hand mixing and two minutes for machine mixing. In all cases the sand and cement must be thoroughly mixed dry before adding any water.

320. Molding. The mortar for making sand tests shall be placed in the mold in four layers of about equal thickness, each of which shall be compacted with a brass rammer weighing one (1) pound and having a flat striking end of three-fourths ($\frac{3}{4}$) of an inch diameter or seven-tenths ($\frac{7}{10}$) of an inch square with rounded corners. This rammer is to be given a drop of one-half ($\frac{1}{2}$) inch with thirty (30) drops for each layer evenly distributed over same. That is to say, the tapping or ramming is to be done as follows: while holding the forearm and wrist at a constant level, raise the rammer with the thumb and forefinger about half an inch and let it fall freely, repeating the

operation until the layer is uniformly compacted by thirty taps.

The excess mortar at top of mold shall be removed with a sharp blade and top of briquette smoothed with trowel without further compacting. The briquette need only be finished on the upper side with the trowel.

8. STORAGE OF TEST PIECES

321. In General. All test pieces for soundness and tensile strength will be placed in a moist closet or under a damp cloth as soon as made, and there remain until the end of the first twenty-four (24) hours. After the expiration of the first twenty-four (24) hours the test pieces will be placed in their respective places of storage, and there remain until completion of tests.

The test pieces must be protected from currents of air and from the direct rays of the sun.

322. Use of Moist Closet. The briquettes should be placed in a damp chamber (zinc lined) furnished with a lid (also zinc lined) to prevent the irregular drying of the briquettes. Great care must be taken to keep the air space in the moist closet saturated.

323. Use of Damp Cloth. Where a moist closet is not available, a cloth may be used and kept uniformly wet by immersing the ends in water. The cloth shall be kept from direct contact with the test pieces by means of a wire screen or some similar arrangement, and be protected from dust.

324. Storage in Water. After twenty-four (24) hours in moist air, the test pieces for longer periods of time shall be immersed in water maintained as near 21° C. (70° F.) as practicable. Test pieces may be stored in tanks or pans, which should be non-corrodible material, and shall be completely submerged during the whole period of hardening. The water should be renewed twice a week for the specified time if running water is not available for a slow current. Some specifications allow the water to be renewed every week.

If test pieces are immersed in sea water, renewal should take place every two days during the first week, and after that every week.

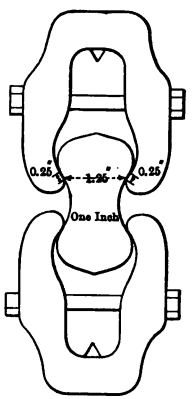
9. TENSILE STRENGTH

325. In General. The tests for tensile strength are to be made immediately after taking from the water or while the briquettes are still wet.

The tests are to be made upon briquettes one (1) square inch at place of rupture and of the form recommended by the Committee of the American Society of Civil Engineers, held when tested by close-fitting metal clips, without rubber or other yielding contacts. The breaks considered in the tests are to be those occurring at the smallest section, one (1) inch square.

326. Number of Tests. For ordinary practice two or more briquettes, generally three, will be sufficient for each set of tests.

327. Size of Clips. The bearing at each point of contact shall be one-quarter ($\frac{1}{4}$) of an inch wide, and the distance between the center of contact on the small clip shall be one and one-quarter ($1\frac{1}{4}$) inches. (See Fig. 5.)



FORM OF CLIP
FIG. 5.

328. Type of Testing Machine. The tests may be made on any standard machine. Testing machines shall be of the positive lever automatic type, so arranged as to apply the loads quietly and uniformly. A machine that applies the stress automatically at a uniform rate is preferable to one controlled entirely by hand. Either Fairbanks or Riehle machines may be used for breaking briquettes in a test for tensile strength.

329. Testing Briquettes. Care shall be taken in centering the briquettes in the testing machine. The load shall not be applied too suddenly. Care must also be taken that the clips and the sides of the briquette be clean and free from grains of sand or dirt, which would prevent a good bearing. The load shall be applied at the rate of six hundred (600) pounds per minute. The pull should be central, along the axis of the briquette. Only briquettes breaking in the smallest transverse sections are to be accepted as satisfactorily tested.

330. Expressing Results. The results of tests will be expressed by saying that "the resistance to tension measured by operating on standard briquettes in the shape of a figure 8 (see Fig. 3), one square inch in cross-section is so many pounds per square inch." No record to be taken of briquettes breaking at other than the smallest section.

331. Measuring Breaking Area of Briquette (Alternate Clause). In determining the tensile strength of briquettes, the area of the broken surface shall be measured with great accuracy, as errors exceeding 10 per cent are otherwise possible.

332. Average Results. The average results for each set of briquettes made at one time shall be considered the governing test, excluding any results which are manifestly faulty.

333. Highest Result (Alternate Clause). The highest result from any sample shall be taken as the strength of the sample when the break is of the least section of the briquette. That is to say, only the highest test of the group is to be taken as the strength of the cement.

334. Decisive Tests. The decisive tests shall be considered as the average of five briquettes. The extreme variation between the mean of five briquettes should not be over fifteen (15) per cent.

10. CONSTANCY OF VOLUME OR SOUNDNESS

335. In General. The soundness of the cement will be determined by mixing the cement, and molding same on glass into pats about three (3) inches in diameter, and about one-half ($\frac{1}{2}$) inch thick in center with thin edges, not over one-eighth ($\frac{1}{8}$) inch at the circumference.

The signs of change in volume are generally shown after three days; in any case an observation of 28 days is sufficient.

336. Making Pats. Pats or cakes of neat cement shall be made by rolling the cement paste into balls and flattening to the form specified, care being taken to thoroughly work the cement so as to prevent any cracking at the edges on account of initial stresses. Pats must be protected from drafts of air, and from jarring. The pats, especially those of slow-setting cements, should be protected from drying out by storing in a covered box until the setting is finished.

337. Classes of Tests. Tests for constancy of volume or soundness may be divided into two classes: (1) Normal tests, or those made either in air or water maintained in air at about

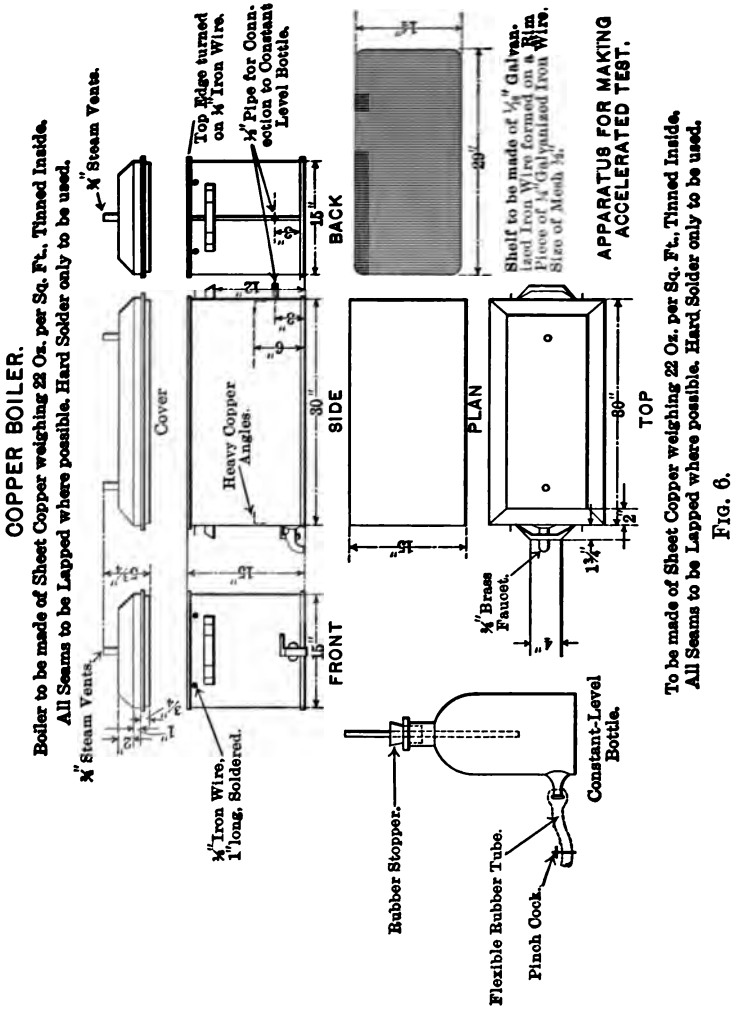


FIG. 6.

21° C. (70° F.), and (2) Accelerated tests, or those made in air, steam, or water at a temperature of 45° C. (113° F.) and upward. The pats will be subjected to the boiling test, cold-water test and air test, unless otherwise specified.

338. Normal Tests. (*a*) Cold-water test will consist of placing a pat after twenty-four (24) hours old, in water maintained as near 21° C. (70° F.) as possible for twenty-eight (28) days.

(*b*) Air test will consist of subjecting a pat after twenty-four (24) hours in moist air to the atmosphere of the laboratory, and observing at intervals.

339. Accelerated or Boiling Test. The boiling test will consist of placing a pat after twenty-four (24) hours in moist air, on a screen in steam over boiling water in a loosely closed vessel for five (5) hours. (See Fig. 6.) Some specifications require that the pat be exposed to an atmosphere of steam for three hours, and then to be submerged in boiling water for three hours. Other accelerated tests use moist hot air, steam and hot-water, steam or water under pressure, dry closets under a temperature above boiling-point, and a gas flame. The steam and hot-water tests are most uniform and satisfactory and the boiling test is much the easiest of applications.

340. Test Requirements. There must be no change of color or form or checking, cracking or disintegration of the pat when subjected to the above tests.

Should the pat leave the glass plate, distortion may be detected best with a straight-edge applied to the surface which was in contact with the plate.

341. Use of Glass Tube. In addition to the above tests for determining the soundness of cement the following may be employed.

A small quantity of cement should be mixed with only sufficient water to give it the consistency of wet sand, and then immediately pressed into a glass tube of about one-half inch in diameter. Within two or three days any swelling will show by the glass bursting; or shrinkage, by the cement becoming loose in tube; either defect may be a cause for rejection of the cement.

11. HOMOGENEITY (MICROSCOPICAL TESTS)

342. In General. The magnifying glass may be used to give indications of the degree of homogeneity of cements. Microscopical tests are generally considered to be unnecessary, but they are of some value in determining adulterants and the

character of the grains of cement, thus giving some check on burning and grinding.

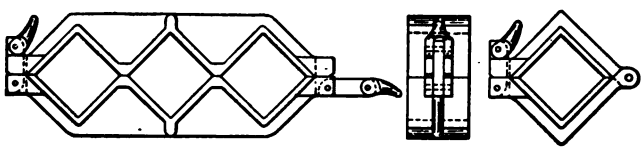
343. Magnifying Powers. Magnifying powers of about three diameters may be used for the general examination and of eight for the detailed examination. From a hand microscope to magnifying powers of 80 to 600 diameters are recommended by various engineers.

344. Identifying Foreign Material. If the examination reveals the presence of grains suspected of coming from foreign materials in the cement, the nature of those may be verified either by complete or partial chemical analysis of the entire product or of the suspected portions, or by any other means that may be judged most suitable to identify the foreign material.

12. MISCELLANEOUS TESTS

345. Compressive Strength. Compressive tests are to be recommended, because compressive strength is required in practice, and because such tests give more reliable results than tensile experiments.

The specimens should be cubes, having each face about 4 square inches in area. They should be prepared like tension



MOULD FOR COMPRESSION TEST PIECES

FIG. 7.

briquettes (see Sec. 7, page 58), but should be left in the molds 24 hours. (See Fig. 7.)

The cube is to be so placed in the machine that the pressure comes upon two lateral faces and not upon the top and bottom faces. That is to say, the pressure should always be exerted on the side and surfaces of the cube, and not on the bottom and upper troweled surface, in order to get a uniform result.

There are several methods of getting a true bearing in the

press or testing machine, truing with trowel, setting against glass and the use of sheets of lead, thick paper or cardboard, plaster of Paris, or fine sand.

Five cubes should be crushed; but in case of dispute, ten must be tested. Compressive tests should be determined after 28 days, it being impossible to accurately determine the cementing power, when comparing different kinds of cement, in a shorter period of time. In other words the strength of various samples of cement may be alike after 28 days, whereas there may be a material difference in the strength of the samples after only 7 days.

The briquettes should be prepared from a mixture of 1 part of cement and 3 of sand.

Bending, adhesion, abrasion, resistance to freezing and resistance to action of sea water are all advised by a few experts, but there are no settled opinions as to their general value and the methods of making them.

346. Transverse Strength. The form and dimensions of the specimens will depend upon the purpose of the test, but should be as large as possible. They should be made in the same manner as the tensile briquettes.

347. Adhesion Tests. Adhesion tests may be valuable in some cases, but no agreement has been reached as to the method of procedure, and many difficulties are generally encountered in making them.

348. Abrasion Tests. Tests for abrasion may be used for cements to be used in floor construction and street pavements. Machines are made for tests of abrasion of cement and concrete.

349. Resistance to Freezing. Tests for resistance to frost are desirable for cements which are to be exposed to the weather and must be arranged according to local circumstances.

350. Resistance to Action of Sea Water. Tests for resistance to the action of salt water must be arranged according to local circumstances.

351. Slag Adulteration. Slag adulteration may be detected by stirring the cement into a mixture of methylene iodide and benzine. When allowed to stand the cement will settle to the bottom, with the slag on top. The density of the mixture must be carefully fixed at the desired amount, say 2.95, by adding the proper amount of benzine.

352. Other Tests. A number of other tests are proposed for special purposes, but they need not be considered here, as the tests given are those which are of most value for commercial purposes, and those not mentioned are of little value unless made and interpreted by experts.

PART VIII

SIGNIFICANCE OF TESTS OF CEMENT

1. SAMPLING CEMENT FOR TESTS

353. In General. At least one barrel in every ten should be sampled and each sample should be a fair average of the contents of the package from which it is taken.

354. Selection of Samples from Sides of Packages. It is certainly desirable to select some samples from the centers of sacks or barrels, but there are many cases where samples taken from the sides of these packages would better determine the suitability of the cement for use. It is no uncommon thing to find the cement near the staves of the barrels, to say nothing of that near the cloth of the sacks, slightly affected by dampness, while the center is entirely unaffected. It may be said, however, that the object of the testing is the determination of the quality of cement in good condition. But on actual work, it is of the highest importance to determine the quality of all cement offered.

2. CHEMICAL ANALYSIS

355. In General. Chemical tests and full quantitative analyses are strongly recommended and preference should be given to cements, of which analyses are furnished by the manufacturers.

356. Magnesia. Chemical analysis should be made when it is suspected that magnesia is present in large amounts, or for mixed cements. The most dangerous feature in Portland cement is the presence of too much magnesia and an excess of free lime, the latter indicated by the cracks and distortions in the test pats or cakes, and the former in the deficiency of tensile strength of the

briquettes. Over 4 per cent of magnesia is excessive and dangerous. Some specifications state that no Portland cement will be accepted which contains more than two per cent of magnesia in any form.

3. FINENESS OF GRINDING

357. In General. The finer the grinding the more efficient and satisfactory will be the action of the cement, other things being equal. That is to say, the more finely cement is pulverized, all other conditions being the same, the more sand it will carry and produce a mortar of a given strength. The most rigid fineness specification could be filled by a cement which would be many degrees too coarse. By a fine cement is not necessarily meant a cement so ground as to show a good sieve test, but rather a cement that contains a large percentage of flour. The same cement may also happen to contain a large percentage of coarse material.

358. Use of Plates. Plates with round holes are to be preferred to wire screens, but it is difficult to manufacture them.

359. Mechanical Sifter. Mechanical shaking has not been found satisfactory, especially for fine cements, and hand sifting is to be preferred.

4. SPECIFIC GRAVITY

360. In General. The specific gravity determination cannot in itself be considered an indication of the adulteration of Portland cement, until placed in comparison with other tests indicating quality. The test for specific gravity is of some value in dealing with one brand of cement, but its determination is not absolutely necessary.

The specific gravity of cement is lowered by underburning, adulteration and hydration, but the adulteration must be in considerable quantity to affect the results appreciably. Specific gravity tests should not be taken as a direct indication of underburning.

The specific gravity of Portland cement depends upon its age, and the opportunities which it has been afforded of absorbing water and carbonic acid from the atmosphere.

5. NORMAL CONSISTENCY

361. In General. In order to ensure the necessary uniformity in carrying out tests for setting, soundness or tensile strength, etc., it is exceedingly important to use a proper percentage of water in making the pastes from which pats and briquettes are made. In fact the results are vitally affected if the proper amount is not used.

362. Determination. The determination consists in measuring the amount of water required to reduce the cement to a given state of plasticity, such that the paste shall leave the trowel cleanly and in a compact mass. That is to say, when the cement is gauged with the proper amount of water it shall form a smooth, easily worked paste, that does not require the trowel to be scraped off or otherwise handled to clean it from the gauged cement. The trial pastes must be made with varying percentages of water until the correct consistency is obtained.

6. TIME OF SETTING

363. In General. This test is seldom used as a basis of comparison, but merely to see if the cement is sufficiently slow in its setting action to be properly manipulated or whether it hardens rapidly enough to satisfy the requirements of the work on which it is to be observed. The setting time of cement has been found to bear an important relation to its strength. If possible, specifications concerning the setting time should not be limited too closely.

364. Slow-setting Cements. If a cement is found to be very slow in setting it is probable that an excess of lime has been used or that the material has been imperfectly ground. Slow-setting cements are apt to be stronger than those which set more quickly.

365. Quick-setting Cements. Quick-setting cements, that is those that set inside of four hours, are apt to be overclayed and are apt to contain less of the active materials to which cement owes its strength. That is to say, if a cement sets very quickly by heating during the mixing process and is found of low tensile strength, it is probable that an excess of clay has been used or that the cement is low in sulphuric acid (SO_3).

Quick-setting cements are not necessarily prompt hardeners; they are usually the reverse.

366. "Flash Set." If a cement has a "flash set" or is extremely quick in this particular but hardens only very slowly, there is a probability that an excess of alumina is involved usually combined with overburning.

367. Temperature. In order to obtain uniform results in determining the setting of cement, it is of importance to carry out tests at a mean temperature of both air and water of 60 to 70° F., as the setting is influenced by the temperature of the air and of the water used in mixing; a high temperature quickens the setting, a low temperature on the other hand, retards it.

7. TENSILE STRENGTH

368. In General. Experience has shown that a great variety of results are obtained with the same cement with different manipulators owing to the varying degree of compression used in filling the molds, varying all the way from the pressure of the finger to hard ramming, and to the varying lengths of time used in mixing, as well as the type and condition of the testing machine.

369. Neat Tests. The neat tests are of less value than those of briquettes made of sand and cement. Some engineers consider the "Neat Test" an unimportant and, therefore, unnecessary requirement, in a specification governing the acceptance of Portland cement for reinforced concrete work. Complete laboratory tests for a scientific purpose demand tests with sand, but the regularity of manufacture of any given brand can be ascertained by testing neat samples. The strength of cement should not be gauged, however, by the results of neat tests, but should invariably be made to depend upon long-time experiments on sand mixtures.

370. Seven-day Test. A high seven-day sand test is an indication of prompt hardening of cement.

371. Twenty-eight Day Test. Cement that will stand a high test for seven days may have an excess of lime, which will cause it to deteriorate. The twenty-eight day test is, therefore, very useful. Any cement not showing an increase of strength

in the twenty-eight day tests over the seven-day tests should be rejected.

372. Extended Tests. Longer tests than twenty-eight days are of value when it is desired to learn the rate of hardening.

8. CONSTANCY OF VOLUME OR SOUNDNESS

373. In General. The test for change of volume is very important, for expansion in any work into which the cement enters would be fatal to reliability. It is therefore highly essential to determine such qualities at once, tests of this character being made for the most part in a very short time. Thin pats or cakes of neat cement allowed to take final set in moist air must withstand indefinite exposure in water or air at any temperature to which the cement may be exposed in the work, without giving any evidence of swelling, checking or warping out of shape, or softening. The constancy of volume of all cement must be perfect.

374. Boiling Test. The boiling water test is designed to ascertain the durability of the cement, and is intended to show in a few hours what would take a long period otherwise. This test is supposed to show whether an excess of free lime is in the cement. Of two or more cements offered, all of which will stand the fresh-water pat test for constancy of volume, the cements that will stand the boiling test also are to be preferred. An unfavorable boiling test should not itself be a cause for rejection, but that chemical analyses be made and the boiling test repeated at a later period.

375. Unsatisfactory Boiling Test. If a sample fails in the boiling test the shipment should be held for at least 28 days and then a second determination made upon a fresh sample. If the second sample passes the test it indicates that the first sample needed seasoning. If the second test fails and the tensile strength is low the shipment should be considered as suspicious. If a cement fails in a boiling test it is probably that an excess of lime has been used or that the material has been imperfectly ground.

376. Examination of Pats for Cracks, etc. In examining pats for cracks, the fine cracks found on the surface, that cross and recross each other, are not due to expansion, cracking and

disintegration of the cement, but are merely the result of changes of temperature. The cracks due to expansion, cracking and disintegration are wedge-shaped, running from the center and usually accompanied by a certain amount of disintegration, especially at the edges.

377. Shrinkage Cracks. These are usually caused by the use of too wet a mixture or produced by too great rapidity of drying. Dry air will usually produce this effect so that such cracks indicate improper manipulation and not dangerous properties in the cement.

378. Pats which Have Curled up at Edges. Cracks caused by the curling of the edges of the cement away from the glass while the pat still adheres is a common occurrence in air pats and should not be considered dangerous unless extreme in character. It should not occur in water pats. If such cracks are found in water pats they denote the existence of qualities which should ordinarily condemn the sample.

379. Pats which Have Left Glass. Pats which have left the glass because of the mere lack of adhesion in either air or water pats should not be considered dangerous. A curvature greater than a quarter of an inch caused by expansion or contraction should be sufficient to condemn the same.

380. Pats Causing Glass to Break. Occasionally the glass will break while the cement pat still adheres to it. This is not usually indicative of poor quality.

381. Radial Cracks. Radial cracks incident to incipient disintegration should always warrant rejection of the sample.

382. Blotching. If a pat is blotched, special investigation should be given to its cause, which may be either adulteration or underburning.

PART IX

METHODS OF CHEMICAL ANALYSIS OF PORTLAND CEMENT

THE following matter on the methods of chemical analysis of Portland cements is taken from the report of the Committee on Uniformity in Technical Analysis of the Society for Chemical Industry, New York Section.

NEW YORK SECTION SOCIETY FOR CHEMICAL INDUSTRY

METHOD SUGGESTED FOR THE ANALYSIS OF LIMESTONES, RAW MIXTURES AND PORTLAND CEMENTS BY THE COMMITTEE ON UNIFORMITY IN TECHNICAL ANALYSIS WITH THE ADVICE OF W. F. HILLEBRAND.

1. SOLUTION

383. Solution. One-half gram of the finely-powdered substance is to be weighed out and, if a limestone or unburned mixture, strongly ignited in a covered platinum crucible over a strong blast for fifteen minutes, or longer if the blast is not powerful enough to effect complete conversion to a cement in this time. It is then transferred to an evaporating dish, preferably of platinum for the sake of celerity in evaporation, moistened with enough water to prevent lumping, and 5 to 10 c.c. of strong HCl added and digested with the aid of gentle heat and agitation until solution is complete. Solution may be aided by light pressure with the flattened end of a glass rod.* The solution is then evaporated to dryness, as far as this may be possible on the bath.

* If anything remains undecomposed it should be separated, fused with a little Na_2CO_2, dissolved and added to the original solution. Of course a small amount of separated non-gelatinous silica is not to be mistaken for undecomposed matter.

2. SILICA (SiO_2)

384. Silica. The residue without further heating is treated at first with 5 to 10 c.c. of strong HCl, which is then diluted to half strength or less, or upon the residue may be poured at once a larger volume of acid of half strength. The dish is then covered and digestion allowed to go on for 10 minutes on the bath, after which the solution is filtered and the separated silica washed thoroughly with water. The filtrate is again evaporated to dryness, the residue without further heating, taken up with acid and water and the small amount of silica it contains separated on another filter paper. The papers containing the residue are transferred wet to a weighed platinum crucible, dried, ignited, first over a Bunsen burner until the carbon of the filter is completely consumed, and finally over the blast for 15 minutes and checked by a further blasting for 10 minutes or to constant weight. The silica, if great accuracy is desired, is treated in the crucible with about 10 c.c. of HFl and four drops of H_2SO_4 and evaporated over a low flame to complete dryness. The small residue is finally blasted, for a minute or two, cooled and weighed. The difference between this weight and the weight previously obtained gives the amount of silica.*

3. ALUMINA AND IRON (Al_2O_3 AND Fe_2O_3)

385. Alumina and Iron. The filtrate, about 250 c.c., from the second evaporation for SiO_2, is made alkaline with NH_4OH after adding HCl, if need be, to insure a total of 10 to 15 c.c. strong acid, and boiled to expel excess of NH_3, or until there is but a faint odor of it, and the precipitate iron and aluminum hydrates, after settling, are washed once by decantation and slightly on the filter. Setting aside the filtrate, the precipitate is dissolved in hot dilute HCl, the solution passing into the beaker in which the precipitation was made. The aluminum and iron are then reprecipitated by NH_4OH, boiled and the second precipitate collected and washed on the same filter used in the first instance. The filter-paper, with the precipitate, is then placed in a weighed platinum crucible, the paper burned off and the

* For ordinary control in the plant laboratory this correction may, perhaps, be neglected; the double evaporation never.

precipitate ignited and finally blasted 5 minutes, with care to prevent reduction, cooled and weighed as $Al_2O_3+Fe_2O_3$.*

4. IRON (Fe_2O_3)

386. Iron. The combined iron and aluminum oxides are fused in a platinum crucible at a very low temperature with about 3 to 4 grams of $KHSO_4$, or, better, $NaHSO_4$, the melt taken up with so much dilute H_2SO_4 that there shall be no less than 5 grams absolute acid and enough water to effect solution on heating. The solution is then evaporated and eventually heated till acid fumes come off copiously. After cooling and redissolving in water the small amount of silica is filtered out, weighed and corrected by HFl and H_2SO_4.† The filtrate is reduced by zinc, or preferably by hydrogen sulphide, boiling out the excess of the latter afterwards while passing CO_2 through the flask, and titrated with permanganate.‡ The strength of the permanganate solution should not be greater than .0040 gr. Fe_2O_3 per c.c.

5. LIME (CaO)

387. Lime. To the combined filtrate from the $Al_2O_3+Fe_2O_3$ precipitate a few drops of NH_4OH are added, and the solution brought to boiling. To the boiling solution 20 c.c. of a saturated solution of ammonium oxalate are added, and the boiling continued until the precipitated CaC_2O_4 assumes a well-defined granular form. It is then allowed to stand for 20 minutes, or until the precipitate has settled, and then filtered and washed. The precipitate and filter are placed wet in a platinum crucible, and the paper burned off over a small flame of a Bunsen burner. It is then ignited, redissolved in HCl, and the solution made up to 100 c.c. with water. Ammonia is added in slight excess, and the liquid is boiled. If a small amount of Al_2O_3 separates this is filtered out, weighed, and the amount added to that found in the first determination, when greater accuracy is desired. The

* This precipitate contains TiO_2, P_2O_5, Mn_3O_4.

† This correction of $Al_2O_3+Fe_2O_3$ for silica should not be made when the HFl correction of the main silica has been omitted, unless that silica was obtained by only one evaporation and filtration. After two evaporations and filtrations 1 to 2 mg. of SiO are still to be found with the $Al_2O_3+Fe_2O_3$.

‡ In this way only is the influence of titanium to be avoided and a correct result obtained for iron.

lime is then reprecipitated by ammonium oxalate, allowed to stand until settled, filtered, and washed,* weighed as oxide by ignition and blasting in a covered crucible to constant weight, or determined with dilute standard permanganate.†

6. MAGNESIA (MgO)

388. Magnesia. The combined filtrates from the calcium precipitates are acidified with HCl and concentrated on the steam bath to about 150 c.c., 10 c.c. of saturated solution of $Na(NH_4)HPO_4$ are added, and the solution boiled for several minutes. It is then removed from the flame and cooled by placing the beaker in ice-water. After cooling, NH_4OH is added drop by drop with constant stirring until the crystalline ammonium-magnesium ortho-phosphate begins to form, and then in moderate excess, the stirring being continued for several minutes. It is then set aside for several hours in a cool atmosphere and filtered. The precipitate is redissolved in hot dilute HCl, the solution made up to about 100 c.c., 1 c.c. of a saturated solution of $Na(NH_4)HPO_4$ added, and ammonia drop by drop, with constant stirring until the precipitate is again formed as described and the ammonia is in moderate excess. It is then allowed to stand for about 2 hours, when it is filtered on a paper or a Gooch crucible, ignited, cooled and weighed as $Mg_2P_2O_7$.

7. ALKALIES (K_2O AND Na_2O)

389. Alkalies. For the determination of the alkalies, the well-known method of Prof. J. Lawrence Smith is to be followed, either with or without the addition of $CaCO_3$ with NH_4Cl.

8. ANHYDROUS SULPHURIC ACID (SO_3)

390. Anhydrous Sulphuric Acid. One gram of the substance is dissolved in 15 c.c. of HCl, filtered and residue washed thoroughly.‡

* The volume of wash-water should not be too large; vide Hillebrand.

† The accuracy of this method admits of criticism, but its convenience and rapidity demand its insertion.

‡ Evaporation to dryness is unnecessary, unless gelatinous silica should have separated and should never be performed on a bath heated by gas; vide Hillebrand.

The solution is made up to 250 c.c. in a beaker and boiled. To the boiling solution 10 c.c. of a saturated solution of $BaCl_2$ is added slowly drop by drop from a pipette and the boiling continued until the precipitate is well formed, or digestion on the steam bath may be substituted for the boiling. It is then set aside over night, or for a few hours, filtered, ignited and weighed as $BaSO_4$.

9. TOTAL SULPHUR

391. Total Sulphur. One gram of the material is weighed out in a large platinum crucible and fused with Na_2CO_3 and a little KNO_3, being careful to avoid contamination from sulphur in the gases from source of heat. This may be done by fitting the crucible in a hole in an asbestos board. The melt is treated in the crucible with boiling water and the liquid poured into a tall narrow beaker and more hot water added until the mass is disintegrated. The solution is then filtered. The filtrate contained in a No. 4 beaker is to be acidulated with HCl and made up to 250 c.c. with distilled water, boiled, the sulphur precipitated as $BaSO_4$ and allowed to stand over night or for a few hours.

10. LOSS ON IGNITION

392. Loss on Ignition. Half a gram of cement is to be weighed out in a platinum crucible, placed in a hole in an asbestos board so that about $\frac{2}{3}$ of the crucible projects below, and blasted 15 minutes, preferably with an inclined flame. The loss by weight, which is checked by a second blasting of 5 minutes, is the loss on ignition.

May, 1903: Recent investigations have shown that large errors in results are often due to the use of impure distilled water and reagents. The analyst should, therefore, test his distilled water by evaporation and his reagents by appropriate tests before proceeding with his work.

PART X

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INDEX

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A

Abrasion tests, 348
Accelerated tests, 210, 224*a*, 242, 254, 339, 374, 375
Acceptable brands, 28, 29
Acceptance marks on packages, 154
 requirements, 205, 216
 tests, 70 to 84
Accepted cement, 22, 118, 202, 214
Access to all parts of the mill, 184
Accuracy of tests, 77
Activity, see Time of setting.
Additional cement, 20
 requirements, 209, 252
Adhesion tests, 347
Adulterations, 133, 351
Aeration, 66, 87
Alkalies, chemical determination of, 389
Alumina, chemical determination of, 385
American Society of Civil Engrs., methods of testing cement, 63
Amount of cement for fineness test, 272
Amount of water for,
 neat briquettes, 312
 sand briquettes, 318
 setting test, 291
Analysis, chemical, of cement, 76, 88*a*, 173, 268
 methods of Society for Chemical Industry, 269, 383
 significance, 355
Anhydrous sulphuric acid, chemical determination of, 390
Apparatus for:
 briquette making, 306
 fineness test, 271, 274
 normal consistency, 285
 specific gravity determination, 280
 tensile strength determination, 328
 time of setting determination, 289, 290
Approval of brand, 34
Average results of tests, 332

B

Bags, delivery of cement in, 97, 98
Bags or barrels to be marked, 86
Barrels:
 contents of cement, 81, 94
 delivery of cement in, 96
 number of, covered by one set of tests, 129
Benzine, use of, in specific gravity tests, 281
Bids for cement, 60
Bills of lading, 104
Bills, verifying, 50
Blotching of pats, 382
Böhme hammer apparatus, 306
Boiling-water tests, 210, 224*a*, 242, 254, 339, 374, 375
Brands of cement, 26 to 38, 56
 acceptable, 29
 approval, 34
 change in, 31
 color, 133
 composition, 38
 failure, 37
 known, 58

References are to Paragraphs, not Pages

Brands of cement, list furnished contractor, 28
mixing of, 93
questionable, 36
samples, 61
short-time tests, 35
unknown, 30, 50
use limited to three, 32
variety of, 27
Breaking area of briquettes, 331
Briquettes, form of, 298
Briquette making, 297, 310, 314
Briquettes subjected to boiling test, 254
Building ordinances, 2

C

Capacity of:
packages, 81, 94
store-room, 111
Cards, marks or numbers, disturbance of, 120
Care of empty sacks, 46
Carload lots of cement, sampling of, 141
storage of, 113
Certificate of tests from manufacturers, 74, 88
Change in brand of cement, 31
Change in volume, 150. See also constancy of volume or soundness.
Character of mill inspection and tests, 187
Charging cement to the contractor, 43
Chemical analysis of cement, 76, 88*a*, 173, 268
methods of Society for Chemical Industry, 269, 383
Portland cement, 233
significance of, 355
City work, inspection of cement for, 159
Clips, size of, for tensile tests, 327
Color of cement, 33, 235
Composition of cement, 38, 233
Compressive tests, 345
Consistency of mixture, 300
normal consistency, 284
significance of tests, 361
Constancy of volume, 177, 224, 335
classes of tests, 337
natural cement, 241
Portland cement, 231
Puzzolan, 248
significance of tests, 373
Contract work, 3
Cost of testing cement, 64, 80, 186
Cracking of cement, see Constancy of volume.
Credit for empty sacks, 45

D

Damaged cement, 83
Damp cloth, use of, 323
Decisive tests, 334
Defective cement:
rejection of, 12, 84, 208
removal from premises, 12*a*
removing work due to, 13
Definition of:
natural cement, 236
original packages, 92
Portland cement, 225
Puzzolan, 243
Delivery of cement, 47, 67, 86 to 106
delay in, 102
notice of, 101
unloading cars, 103
Demurrage, 48
Destroying sacks, 24
Deterioration of cement, 90, 108
Determination of:
constancy of volume, 335
fineness, 270
normal consistency, 284
specific gravity, 278
tensile strength, 325
time of setting, 288
Different brands of cement, 27
Disturbance of cards, marks or numbers, 120

References are to Paragraphs, not Pages

E

Elaborate tests, 152
Engineer allowed to enter store room, 112
Engineer's decision, 138
Engineer may test and analyze cement, 127
Examination of pats, 376
 sieves, 275
Expense of laboratory tests, 162
Experienced testers, 218
Exposure to moisture, 211
Expressing results of tests, 330
Extended tests, 131, 213, 372
Extension of time, 137

F

Facilities for:
 sampling, 140
 testing, 146
Factory inspection, 128
Failure of brand, 37
 briquettes to pass tests, 230
 pats to pass soundness test, 232
Field inspection and tests, 145, 181, 204
Final acceptance, 207
Fineness of cement, 219, 270
 amount of cement to be used in test, 272
 apparatus, 271
 hand sieving, 273
 method of determining, 174, 277
 natural hydraulic cement, 237
 percentage, 277
 Portland cement, 226
 Puzzolan, 244
 sieves, 271
 significance of test, 357
Flash set, 366
Form of briquette, 298
 proposal for furnishing cement, 85
Freezing, resistance of cement to, 349
Freight on rejected cement, 12*b*
Furnishing cement in bulk, 195
 to the contractor, 42 to 54

G

General conditions, 1 to 25
Gilmore needles, 290
Glass tube for soundness test, 341
Grade of cement, 26

H

Hammer apparatus of Böhme, 306
Hand sieving, 273
Highest results in tests, 333
Hot tests, see Accelerated or boiling tests.
Housing cement, 109

I

Identifying foreign material, 344
Identity of cement withheld, 169
Ignition, determination of loss on, 392
Information to be furnished, 65
Inspection and tests of cement, 8
 field, 125, 159, 181, 204
 laboratory, 9, 157, 160
 mill, 10, 78, 163, 182
Inspectors, furnishing, 188
Iron, chemical determination of, 386

K

Kerosene, used in specific gravity determination, 282
Known brand of cement, 58

L

Laboratory inspection and tests, 9, 157, 160
Less cement, use of, 21
Lime, allowable proportion, 233
 chemical determination of, 387
List of brands furnished contractor, 28
Lumpy cement, 14, 126

M

Magnesia, 356
 allowable proportion of, 233, 356
 chemical determination of, 388
Magnifying powers, 343

References are to Paragraphs, not Pages

Manufacturer furnishing results of tests, 74, 88
Marking packages, 86, 153
 samples, 167
Meaning of original packages, 92
Measuring cement, 18
Mechanical sifter, 274, 359
Method of sampling cement, 144, 165, 194, 196, 198
 testing cement, 63, 170, 261
Microscopical tests of cement, 234, 342
Mill inspection and tests, 10, 78, 163, 182
 character, 187
 compensation, 80, 186
 copy of tests, 105
 sample, 194
 scope, 190, 191
Miscellaneous tests, 345 to 352
Mixing cement, 93
 paste, 293, 303
 samples, 142, 143
Modifications in test requirements, 209
Moist closet, 322
Moisture, exposure to, 211
Molding briquettes, 305, 313, 320
 pats or cakes, 294, 336
Molds, 304
Mortar box tests, 151

N

Natural hydraulic cement:
 boiling test, 242
 constancy of volume, 241
 definition, 236
 fineness, 237
 microscopic test, 342
 soundness, 241
 specific gravity, 238
 tensile strength, 240
 time of setting, 239
 weight of, per barrel, 81, 94
Neat briquettes, 310
Neat tests of briquettes, 369
Normal consistency, 284, 362
 significance of tests, 361
Normal tests for soundness, 231, 241, 248, 338
Notifying engineer when cement is wanted, 51
Number of briquettes for testing, 299, 311, 315, 326

O

Owner furnishing cement, 42

P

Packages, 91, 92, 201
 capacity of, 94
Packing of cement, 95
Pats causing glass to break, 380
Pats, molding of, 294
Pats which have curled up at edges, 378
 left glass, 379
Percentage of fineness, 277
Physical tests of cement, see Tests of cement.
Plates for sifting cement, 358
Portland cement:
 chemical composition, 233
 color, 235
 constancy of volume, 231
 definition, 225
 fineness, 226
 fresh, use of, 25
 miscroscopic test, 234, 342
 setting qualities, 124
 soundness, 231
 specific gravity, 227
 tensile strength, 229, 257
 time of quick setting, 256
 time of setting, 228
 use, 2
 weight of, per barrel, 81, 94
Preference for slow-setting cements, 6
Preservation of maker's brand on packages, 122
Prohibiting use of questionable cement, 36
Proportions, 265, 301, 316
Proposals for cement, 60, 85

References are to Paragraphs, not Pages

Pulverizing cement, 14
Purchase of cement from manufacturers, 55 to 85
Purchase tests of cement, 55 to 69
Puzzolan cement:
 constancy of volume, 248
 definition, 243
 fineness, 244
 microscopic test, 342
 soundness, 248
 specific gravity, 245
 tensile strength, 247
 time of setting, 246
 weight of, 249

Q

Quality of cement, 1, 71
Quantity of sample, 166
Quantity on hand, 116, 118
Questionable cement, 36
Quick-setting qualities, 256, 365

R

Radial cracks in pats, 381
Records of cement received, given out and rejected, 11
Records of cement tests, 180, 189, 267
Reinforced concrete, 132
Reinspection of cement, 156, 212
Rejected cement:
 freight on, 12*b*
 records of, 11
 removal from premises, 12*a*
Rejection of accepted cement, 215
 cement, 12, 84, 106, 156, 202, 208, 212
 marks on packages, 155
 requirements, 216
Relation of cement and aggregate, 16
Removing briquettes from molds, 307
 rubbish from cement, 15
 work due to defective cement, 13
Repeating tests at laboratory, 157
Reputation of manufacturers, 57
Responsibility for delivery of cement, 89
Resistance to freezing, 349
 action of sea water, 350
Results of tests, 179, 283, 330, 332, 333
Rights reserved, 69
Routine of mill inspection, 191
Rubbish in cement, removal of, 15

S

Sacks:
 care of empty, 46
 contract regarding, 44
 credit for empty, 24
 delivery of cement in cloth, 97
 delivery of cement in paper, 98
 destroying, 24
 ownership of, 68
 marking, 86
Samples, 61, 134, 158, 164, 194, 196
Sampling cement, 62, 73, 114, 139, 165 to 169, 199, 262, 353
Sand briquettes, 314
Sand cement:
 definition, 250
 manufacture, 39
 preparation, 40
 specifications, 41
 test requirements, 251
Sand for cement tests, 135
Scales for weighing cement, 110
Scope of mill inspection and tests, 191, 192
Screening samples, 263
Sealing packages, 200, 201
Sea water, use of cement in, 258, 350
Selection of laboratory, 161
Sending samples to laboratory, 164
Setting aside special bins, 197
Setting of cement, 124, 149, 175, 221
 method of testing, 288, 296
 in sea water, 259
 significance of tests, 363
Setting of cement, time of, 176
 natural, 239
 Portland, 228
 Puzzolan, 246
Setting tests, see Setting of cement.
Seven-day tests, 223, 370

References are to Paragraphs, not Pages

Shipping cement, see Delivery of cement.
Shortage in weight, 82
Short-time tests, 35
Shot in sieves for fineness test, 276
Shrinkage cracks, 377
Sieves, 271, 274
Sifting cement, 292, 302
Silica cement, see Sand cement.
Silica, chemical determination of, 384
Simple field tests, 148
Slag adulteration, 351
Slag cement, see Puzzolan.
Slow-setting cements, 364
Solution, method of, in chemical tests, 383
Soundness of cement, 150, 224
 method of testing, 177, 335
 natural hydraulic cement, 241
 Portland cement, 231
 Puzzolan, 248
 significance of tests, 373
Special requirements, 255
Specific gravity of cements, 278
 apparatus, 280
 benzine, 281
 method of determining, 282
 natural hydraulic cement, 238
 Portland cement, 227
 Puzzolan cement, 245
 results, 283
 significance of tests, 360
 temperature, 279
Standard sand, 317*a*
Steam tests, see Accelerated or boiling tests.
Storage of briquettes, 309
 test pieces, 295, 309, 321, 324
Storage of cement, 23, 49, 107 to 124
 car-load lots, 113
 in the open, 121
 sampling and marking, 114
 storehouse, 110, 111, 112
 use, 115
Strength, see Tensile strength, Compressive strength, etc.
Sulphur, chemical determination of, 391
Sulphuric anhydride, chemical determination of, 391
Supervision of tests, 183

T

Tagging accepted cement, 214
Temperature, 264
 setting of cement, 367
 specific gravity, 279
Tenders for cement, 60
Tensile strength of cement, 178, 222
 method of testing, 325
 natural hydraulic cement, 240
Tensile strength of cement, Portland cement, 229
 Puzzolan, 247
 quick-setting, 257
 significance of test, 368
Tested cement, 136
Testing briquettes, 329
Testing house for cement, 147
Testing machine, type of, 328
Tests of cement:
 abrasion, 348
 accelerated, 210, 224*a*, 242, 254, 339, 374, 375
 acceptance, 216
 adhesion, 347
 adulterations, 351
 boiling water, see Accelerated.
 briquettes placed in sea water, 260
 classification of, 216
 compressive strength, 345
 constancy of volume, 231, 241, 248, 335
 decisive tests, 334
 elaborate, 152
 extended, 131, 213, 372
 final, 206
 fineness, 226, 237, 244, 357
 hot, see Accelerated.
 microscopical, 234. 342
 miscellaneous, 345 to 352
 mortar box, 151
 normal consistency, 284
 purchase, 55

References are to Paragraphs, not Pages

Tests of cement:
resistance to action of sea water, 350
resistance to freezing, 349
required, 172, 193, 217
results of, 179, 189, 330, 332, 333
sea-water, 258, 259, 260
seven-day, 223
short-time, 35
simple method for normal consistency, 287
soundness, 224. See also Constancy of volume.
special requirements, 255
specific gravity, 227, 238, 245, 278
tensile strength, 229, 240, 247, 257, 325, 368
three-day tests, 209a
time of setting, 228, 239, 246, 253, 288
tri-monthly, 213a
where made, 75
see also, Natural, Portland and Puzzolan cements.
Testing cement:
according to contract, 72
ample supply of cement, 116
cost, 64
field, 145, 181, 204
methods of Am. Soc. C. E., 63, 261
laboratory, 9, 157, 160
limits of accuracy, 77
mill or factory, 10, 78, 163, 182
proportions, 265, 301, 316
results furnished by manufacturer, 74, 189
screening samples, 263
supervision, 183
temperature, 264, 279
water, 266, 291, 300, 312, 318
see also, Natural, Portland and Puzzolan cements.
Test requirements for cement, 217
Three-day tests, 209a
Time of delivery of cement, 99
sending samples, 168
Time of setting, 5, 221, 253
natural cement, 239
Portland cement, 228
Puzzolan, 246
Total sulphur, chemical determination of, 391
Transverse strength, 346
Twenty-eight day tests, 371

U

Uniformity of product, 130
Unit of measure, 17
Unknown brand, 30, 59
Unloading cars, 103
Unnecessary use of cement, 52 to 54
Unsatisfactory boiling test, 375
Untested cement, 117
Use limited to three brands, 32
Use of fresh cement, 25
Use of tools, labor, etc., 185

V

Variety of brands of cement, 27
Varying cost of cement, 7
Vicat needle, 285, 289
Visiting laboratory, 171
Volume, constancy of, see Constancy of volume or soundness.

W

Waste of cement, 52
Water for cement tests, 266, 291, 300, 312, 318
Water, storage of test pieces in, 324
Weighing cement, 19, 123
briquettes, 308
Weight of packages of cement:
natural, 81
Portland, 81
Puzzolan, 81, 249
shortage in, 82

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